White Paper

The Linear Positioning Systems White Paper for Manufacturers of Additive Manufacturing and 3D Printing Systems

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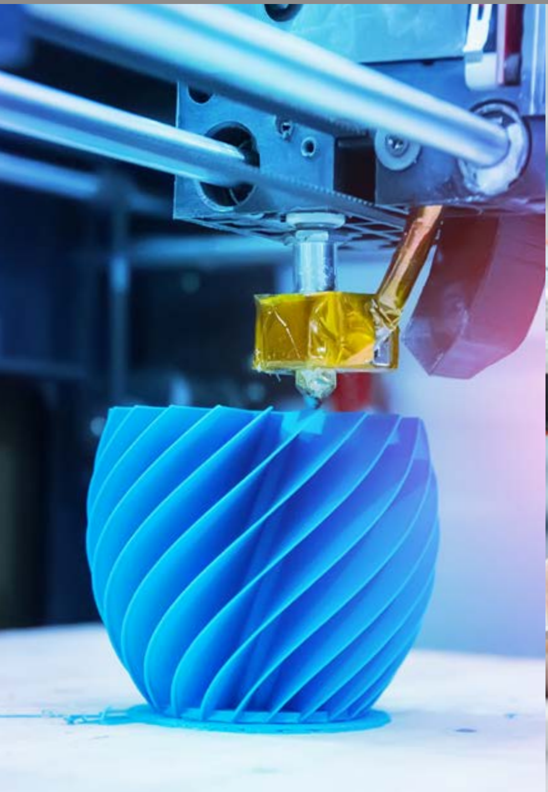

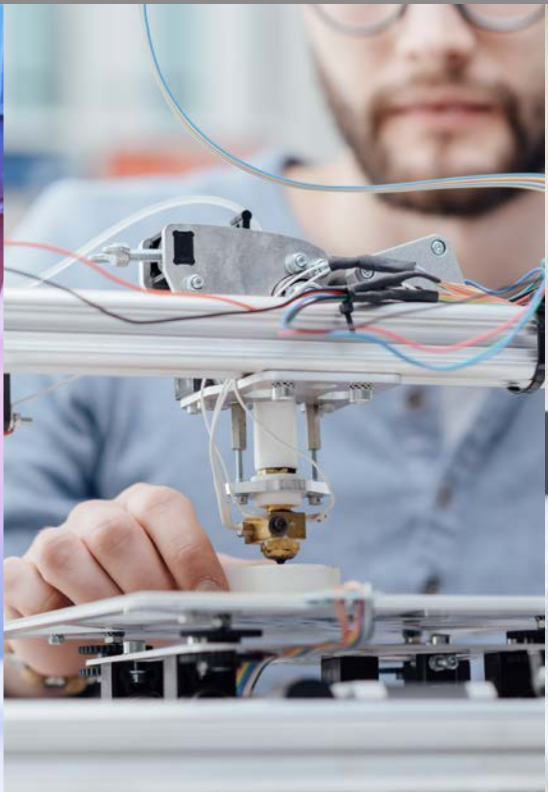

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Introduction

The product design engineers, mechanical engineers, and design engineering managers at the world's leading manufacturers of additive manufacturing and 3D printing systems are charged with turning their visions, designs, and the potential of technology into the reality of equipment, systems, and solutions. The challenges include accuracy, precision, miniaturization, customization, biomaterials, and operational safety.

Besides new additive manufacturing and 3D printing technologies and their myriad of current and future applications, designers must also stay abreast of new developments and essential functionalities in critical core components. These include the linear positioning systems that enable their printer components to function according to design.

Additive Manufacturing, 3D Printing, and Linear Positioning

Linear positioning components are critical in successfully operating additive manufacturing systems and 3D printers. They must precisely guide the movement of the unit's print head, nozzle, laser, or electron beam — and sometimes its material bed. It is a requirement for every relevant additive manufacturing technology, including bioprinting, stereolithography and sintering, direct metal laser sintering, direct metal laser melting, and electron beam melting.

In the genre of low-cost 3D printers, new and modified desktop options still regulate linear movements using the exact mechanisms that 3D printing pioneers employed, such as bushings, belt drives, steel rods, and basic ball bearings. This arrangement is inexpensive and provides adequate control for many more straightforward 3D printing tasks.

However, designers from industrial-sized additive manufacturing systems to smaller 3D printers are turning to more advanced linear positioning solutions, such as profiled linear guideways with ball bearings or rollers. They cost more than belt and rod systems — averaging 3-times more expensive. But their advantages for more advanced additive manufacturing and 3D printing applications are decisive.

Their much higher degree of stiffness enables printing that virtually eliminates frustrating printer problems such as ringing or backlash. They also help avoid other issues of rod and belt arrangements, which are often too tight (so movement suffers from roughness or binding) or too loose (so movement is affected by excessive play in the mechanism).

Instead, a linear guideway's high-precision machined tolerances ensure ultra-smooth motion and positioning.

Once the application moves above the ability for accommodation by a desktop solution or beyond the need to create a one-of-a-kind prototype, modern printing technology is required to fulfill the challenges of complex additive manufacturing and 3D printing applications. Additive manufacturing and 3D printing systems dedicated to these

Two-axis positioning system used to position microscopes accurately.

applications require implementation at an entirely new level of linear positioning performance. As a result, manufacturers of such systems must contract with suppliers that can furnish a linear positioning solution with much higher degrees of critical characteristics such as rigidity, speed, and precision.

Modern linear positioning components often applied to additive manufacturing and 3D printing systems include profiled guideways with balls, profiled miniature guideways, miniature balls screws, and linear positioning systems.

Integration is a continuing trend. Why buy a rail or a slide plus a separate encoder and then encounter difficulties aligning them? Specifying the guideway with an integrated encoder/measuring system can save setup time and trouble while reducing the total cost of ownership.

Maintenance is likewise a vital issue. To simplify maintenance, focus on features such as integrated long-term lubrication features or materials with extended wear resistance.

Successful Partnering for Critical Expertise

Manufacturers of additive manufacturing and 3D printing systems are experts in their own right. But many have limited resources when the challenge rests in the specifics of linear positioning technology. Partnering with an experienced linear positioning supplier can, in effect, extend your engineering team.

Shape working supplier relationships to build the best basis for a successful project:

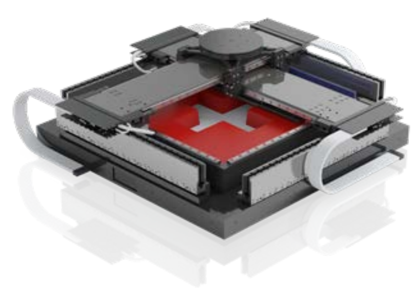
1. Start early. Call in the linear positioning technology supplier near the start of the design process, arrange a nondisclosure agreement (NDA), and leverage the supplier to scope and quantify linear positioning requirements upfront. This gives the supplier maximum time and scope to recommend the right solution, from initial planning to final design freeze.

2. Design to performance. Expect the supplier to quickly pinpoint any positioning issues and opportunities a given design may present. Expert suppliers can identify trade-offs and suggest alternatives. The goal: Avoid pitfalls now to prevent performance shortcomings later when they are harder to correct.

3. Design to cost. In the real world, budgets are always a prime concern. Share the intended market price of the printer with the supplier. An experienced supplier will strive to meet it without sacrificing quality or extended service life. The ultimate goal is to strike the best balance of delivering optimal performance with the lowest total cost of ownership over the printer's lifetime.

4. Explore custom options. Many times, standard, off-the-shelf components won't fit or can't deliver the proper performance for a specific design. Keep the options open. Avoid "take-it-or-leave-it" supplier relationships. The right partner will tailor their solutions to the unique specifications and demands of the design and application. Customized linear positioning components and systems can improve the design process, performance, and total cost of ownership.

Besides expertise with customization, the right supplier will bring a wide array of linear positioning offerings to the challenge. OEM engineers can benefit from their versatility of drawing on a range of linear solutions — such as anti-friction guideways, profile linear guideways, bearings and racks, positioning systems, linear ball bearings, and ball screws. Such components can be intelligently combined in a system with the rigidity, speed, and precision to deliver the performance demanded in additive manufacturing and 3D printing systems.



Twin gantry positioning system used for biomedical/medical applications, such as microscopy, bioprinting tissue, and organ regeneration.

Rigidity

The performance of an additive manufacturing or 3D printing system's linear positioning solution rests, literally and figuratively, on its base.
Wherever high performance is required, sufficient rigidity or stiffness demands close attention to factors such as thickness, frame construction, and materials. All must be consistent with the final performance specifications you want to achieve.

Rigidity affects factors such as flatness and straightness. For example, a manufacturer may attempt to attach a linear positioning rail made of stainless steel, of required thickness and suitably rigid design, to an aluminum plate thinner than the rail. The inevitable result: deflection. (Linear positioning components are typically designed to resist forces along the X, Y, and Z axes to prevent this.) Here, the deflection would mean that the rail could curve, however slightly, in the direction dictated by any force applied. This affects smooth travel and repeatability, degrading the printed product's uniformity.

But even the most advanced linear positioning products can't deliver superior speed or precision if they rest on a base that allows extraneous movement. Traditionally, most 3D printers have been mounted on structures such as sheet metal cabinets or aluminum tables. Unfortunately, these bases won't deliver the acceptable rigidity demanded by modern additive manufacturing and 3D printing equipment. So instead, the recommendation is for strongly built steel or iron structures or granite bases.

Another innovative choice is a substructure composed of minerals and epoxy resins. These mineral cast bases furnish printer beds with excellent vibration dampening, strong chemical resistance, and excellent thermal stability. In addition, they can be formed to accommodate any contours and dimensions a given printer requires, including custom-shaped openings, spaces, and wiring channels. They also offer clear technological, economic, and ecological advantages over steel, gray iron, or cast iron.

Discuss expected loads and printer configuration with the linear positioning supplier early so that the resulting system is designed from the start to withstand all the forces and conditions and meet all the accuracy and precision requirements of itsintended application.

Speed

The travel speed of a linear positioning system essentially defines the printer's production speed.

Relatively slow speeds are required for some additive manufacturing and 3D printing systems tasks to prevent such issues as deformation. On others, excessive travel acceleration can create problems from ringing to ghosting to lack of layer adhesion to filament blobbing. In most cases, manufacturers ask linear positioning suppliers to deliver maximum speed wherever possible.

When the highest productivity or output is required, the linear positioning element must be able to accelerate as rapidly as possible. But settle time is often another key metric: how long it takes the rail or other component attached to the moving part (print or beam head, material bed, etc.) to come to rest without appreciable vibration after each acceleration step. However, such factors greatly depend upon the printer design, the material, shape, thickness, resolution, and other characteristics of the specific item the printer produces; and which linear positioning components are employed. Generally speaking, in an optimum configuration,

Three-axis positioning system for ultra-high precision medical scanning and processing.

some of today's high-performance linear positioning systems can attain constant velocities with step-and-settle intervals — even at exact positions — of as low as 50 milliseconds. That would allow extremely rapid travel to support the fastest industrial printers available today, which operate up to 1000 millimeters a second. A discussion between manufacturer and supplier is required to determine what can be achieved in any specific application.

Precision

The choice of linear positioning equipment directly impacts the degree of positional accuracy and repeatability — the precision — that an operating additive manufacturing and 3D printing systems demand. Therefore, the linear positioning technology will impact the end application's critical performance requirements, including accuracy, repeatability, and resolution.

If the end user in an additive manufacturing or 3D printing process employs after-print finishing steps to attain given tolerances or flatness/smoothness specifications, extreme precision in primary printing may not be necessary. However, a good linear positioning system for this range of printers might deliver positional precision down to plus or minus 50 or 100 microns.

However, internal features of the finished item may not be easily accessible after completion. Additionally, leading additive manufacturing and 3D printing system designers and manufacturers are evolving their approaches to minimize extra finishing. Thus, an extremely accurate linear positioning may be required to achieve precise dimensions and shapes at every point.

Many additive manufacturing and 3D printing applications are now exceeding the level of linear positioning equipment precision traditionally required by high-performance machine tools. And as technologies continue to evolve, expect many applications to demand even higher degrees of precision — such as leading linear positioning suppliers' design into ultra-precise nanoscale equipment for semiconductor manufacturing. For additive manufacturing and 3D printing system requirements that fall into these latter groups, a linear positioning technology supplier must be willing and able to consult on specific requirements. The supplier must compare the exact capabilities of possible linear positioning solutions that will enable the manufacturer to achieve new levels of precision.

Much depends on the specific printer design and on the item that must be bio-printed. Beyond, a linear tech supplier must address issues from the linear positioning system's stiffness, flatness, load/preload, and construction materials to its operating temperatures and vibration/resonance potential, as well as considering factors such as constant velocity and stroke length. But under the right conditions, a superior linear positioning system today can enable particular additive manufacturing and 3D printing systems (for example, bioprinting) to attain repeatable accuracy from 0.5 down to 0.1 microns.

Moving into the Future of Bioprinter Manufacturing

Today's advanced linear motion systems can, and are, delivering the precision that bioprinting applications can demand.
As bioprinter manufacturing continues its explosive development, speeds will increase, efficiencies will grow, and the use of biomaterials will proliferate.

There is ample room for bioprinters' linear motion capabilities to grow. For instance, precisely controlling the movement of dispensing elements on smaller and smaller scales can empower bioprinters to manufacture ever-finer somatic structures. Vein tissue was first successfully printed in 2016. Fully functional 3D-printed human organs are predicted in the not-so-distant future.

The Bottom Line

An increasing number of leading additive manufacturing and 3D printing system manufacturers are exploring the benefits of advanced linear positioning solutions for their challenging, cutting-edge, and in many cases, unique products. The right linear positioning systems supplier can overcome concerns and obstacles to help deliver advantages such as expert design, acceptable lead times, reduced cost of ownership, reliable quality, and rewarding partnership. In addition, the right linear technology can provide critical characteristics such as rigidity, speed, accuracy, precision, miniaturization, customization, material compatibility, and biosafety that enable truly high-performance additive manufacturing and 3D printing.

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