Rethinking Engineering – A Holistic Approach to Generating Optimized Linear Motion Design Solutions

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Original equipment manufacturers (OEMs) designing products that incorporate linear motion systems need to achieve the right balance of functionality, performance, durability, energy consumption and other attributes that will enable their product to outperform competition. Design engineers should take a 360 degree view of all reasonable alternatives while locking down the few truly key critical parameters and keeping as many design parameters undefined for as long as reasonably possible. Maintain a fluid process with multiple options as contingencies. Develop a robust product development process marked by milestones and formal design reviews. Consider the use of modified or configured parts and assemblies that offer the exact features you need at a cost that is at or close to standard components. Find the right development partner that offers a broad portfolio of products and strong engineering expertise and support. Take advantage of online selection and configuration tools to design, size and select your linear motion system. The net result will be higher product performance, reduced installed cost and shorter development cycles.

Consider all your options

Linear motion systems are widely used to guide, support, locate, and accurately move machinery components and products in a wide range of automation applications because they provide low friction, smooth, accurate motion for nearly any moment or normal loading condition. Major applications include factory automation, medical, packaging, machine tool, semiconductor, printing, automotive assembly, aerospace and food processing. Engineers designing linear motion systems can choose from a wide range of choices among the basic building blocks. For example seven technology groups are used in large numbers of applications, including lead screw drives and ball guides, lead screw drives and slide guides, ball screw drives and ball guides, ball screw drives and slide guides, belt drives and ball guides, belt drives and slide guides, and belt drives and wheel guides. Selecting the technology group that best fits the application is critical but only one part of the process of designing a linear system.

It's critical to carefully consider all of your options in designing a linear motion system. In many cases, experience with previous designs can serve as a limiting factor because it predisposes engineers to follow a particular path such as by making basic decisions like the type of linear system technology in the early stages of the design process without carefully considering alternatives. Substantial improvements can often be achieved by undergoing a systematic selection process for linear motion technology at a stage in the design process when requirements are being fully defined. Keeping all options in mind anticipating possible specification changes and scope creep due to requirement changes or unforeseen environmental conditions, physical, monetary, or otherwise, it may be helpful to create a matrix/table of product options by features, dimensions, performance specifications, etc.; Pareto them if necessary. This approach ensures that the linear motion technology is selected to match the requirements of the application rather than the other way around.

Figure 1: Profile rail bearing linear guide

Specifying, for example, a profile rail system for a new design because it is familiar and has been used in your last few designs may seem like a way to save time but could easily result in a less than optimal design. Profile rail or square rail systems are one of the two major types of linear guides – the other is round rail systems. Profile rail systems are popular because they generally offer higher accuracy, higher rigidity, higher load-life capacity, and are also very compact. The ball track groove in profile rail guides is only slightly larger in radii than that of the balls themselves. The geometry cradles the balls as they infinitesimally flatten under load, slightly expanding the contact area between the balls and the races. As a result, generally profile-rail bearings are roughly 10 times stiffer than a traditional round rail assembly with ball and shaft surfaces that are convex.

Figure 2: Round rail ball bushing bearing components (Super Ball Bushing bearing shown)

But an aspect of concern for profile rail bearings is that the mounting surfaces must be precise which makes them more difficult to install. Profile rail designs are especially sensitive to flatness errors that can cause binding. Surfaces must be carefully prepared or the parts may need to be shimmed and adjusted during installation. On the other hand, round rail ball bushing bearing systems accommodate torsional misalignment caused by inaccuracies in carriage or base machining or machine deflection with little increase in stress to the bearing components. The self-aligning-in-all-directions design of round rail bearings is forgiving of poor parallelism and variations in rail height. As a result, these bearings allow for smooth travel when mounted to wider-tolerance prepared surfaces.

So it's important to weigh the pluses and minuses of each type of linear guide when designing a linear motion system. If high accuracy and high load capacity are critical, then profile rail systems are probably your best choice. If the accuracy and load requirements of this particular application are not that great, then it may make sense to go with a round fail system because their lower sensitivity to alignment makes them more robust which is particularly important in a rugged environment such as factory automation and manufacturing.

Robust design process

Figure 3: Robust product development process

Decisions such as this are often critical to the performance of the product. For this reason, gate mechanisms are often used to provide technical and general management with oversight and control over go or no-go decisions. Design reviews are scheduled to occur at defined points in the process where the product or process design is assessed before the project continues. The review team should consist of members who are knowledgeable about the technology involved but not directly involved in the project in order to provide objective viewpoints. Reviews should not be limited to simply the design of the product but should also address the lifecycle requirements of the product, such as product portfolio consolidation or extensions as well as program requirements such as cost, schedule and risk.

Consider modified or configured parts and assemblies

In many cases, the importance of the technology selection decisions is matched by the importance of modifications and customizations that more closely match the performance of the linear motion system to the requirements of the application. The future of mechanical motion control won't necessarily be marked by major advancements in the technologies themselves, but rather by the specification of cost-effective components that precisely match a machine's performance requirements. This approach is superior to the conventional practice of designing the machine around off-the-shelf components that most closely match performance needs.

Increasingly, components suppliers are offering modified or configured parts and assemblies that provide the exact features, performance and form factor that the OEM is looking for at a price and delivery time that is at or close to the cost of standard components. Another approach to modified parts and assemblies involves configuring a standard linear actuator to optimize its performance in a specific application. In some cases, the components supplier can provide field test equipment that is used to measure the loads and stresses on the actuator. The supplier then configures an existing linear actuator to efficiently fit that specific performance profile by modifying its length, mounting options, feedback options, cabling and connectors, operating speeds and other options.

Technological advancements are also increasing the ability of OEMs to obtain a configuration optimized for their product without investing in a complete custom solution. An example is combining electric actuators with electronic controls to add cutting edge features that improve performance, ergonomics, safety, and cost. In this case, the OEM provides these features by writing software.

This trend towards configured or customized solutions will help OEMs achieve success in the market by optimizing their product for customers' requirements without the expense of a custom solution. As a result, OEMs and Tier 1 suppliers are increasingly seeking out the expertise of motion control vendors to deliver configured solutions rather than just components to reduce total landed cost, time to market, and ultimately delight the end customer.

Select a supplier with broad capabilities

Linear motion suppliers with a broad range of field proven products and superior technical expertise and support are best positioned to meet these requirements. For example, Thomson's linear motion systems cover a development span of 60 years and combine to meet virtually every linear motion system need. Our linear motion system drives include screw-driven systems for high thrust, stiffness and tight precision in high-load, moderate-speed applications. Belt-drive linear motion systems are provided for applications where acceleration and speed are the most important criteria. Thomson linear motion system guide technology offers high-precision ball guides, robust prism guides, and high-speed wheel guides. Thomson linear motion system products offer added features, such as anti-contamination cover bands, single or double (left/right moving) carriages, central lubrication, and single/multi-axis solutions.

Online configuration tools

This wide range of standard, modified or configured parts and assemblies can be designed, sized and selected through online selection and configuration tools. For example, a new approach to linear systems design enables OEMs to configure custom assemblies that are matched specifically to the requirements of their application based on economical and readily available standard components. The user enters the key parameters of the application including mounting configuration, positioning requirements, environmental conditions, loading conditions and motion requirements.

These requirements are filtered through a comprehensive set of calculations such as linear bearing load/life, ballscrew load/life and ballscrew critical speed. The application then presents a listing of products that meet the basic requirements. The user can easily evaluate the features, performance, cost and durability of these various configurations and pick the one that optimizes the final product to meet the requirements of the market. The design tool then provides outputs that include 3D models, pricing, delivery times and ordering information. One example is Linear MOTIONEERING® (www.linearmotioneering.com) which works as follows:

Step 1 is establishing the system orientation. The user picks the application's orientation: inverted, vertical, horizontal side or horizontal. Then the user selects the mounting configuration – fully supported, end supported or intermittently supported.

In step 2, the user enters the positioning requirements and the stroke length which is defined from hard stop to hard stop. The user selects whether the positioning requirement will be defined in terms of accuracy, repeatability or maximum allowable backlash. The user then selects a value for the choice that was selected.

Step 3 involves defining the environmental conditions which are critical in determining the correct material selection, cover strategy and lubrication scheme. The user selects a condition from the following choices: clean, water/chemical spray/fog, impact/press application/vibration, moderate to heavy dust particulate count, high pressure/temperature washdown, water/chemical splash and clean room. Based on the environment selection, the application will recommend linear slide options such as chrome plated ball guide, stainless steel ball guide, Raydent surface ball guide, CR linear bearings, polymer plain bearings, etc. The user can change these options.

In step 4, the user enters the load and applied force. The load is the weight that the carrier or saddle supports, including the payload, fixturing and tooling. The user locates the center of gravity of the load with respect to the center of the carriage/saddle by entering x, y and z values. The user enters the applied or external force. This process related force is assumed to be exerted at the center of gravity of the load.

Figure 4: Application calculates minimum acceleration move profile (green), recommended move profile (black) and maximum acceleration move profile (red). Screen shot from Linear MOTIONEERING (www.linearmotioneering.com) web-based sizing and selection tool.

Step 5 involves entering the move profile requirements. The user enters the move distance, move time and dwell time. The program determines the appropriate acceleration rates for each individual system that meets the requirements of the applications. The user then selects one of the systems in the solution set. The application presents several move profiles. The green move profile is based on maximum acceleration and the red move profile is based on minimum acceleration. The user determines a recommended move profile between the maximum and minimum and provides the desired acceleration rate.

Based on the recommended move profile, the application calculates the bearing and drive loads, and ball screw critical speed. The user can also enter the acceleration rate. When the user does so and presses the update button, the application presents the user's selected move profile and updates the safety factors based on the new move profile.

Finally, the user has the opportunity to select options such as motor mounts, cover type, brake, limit switches, and gearhead. The application presents the total price of the system, and dimensions. The user can download a 3D CAD model of the solution in the native format of 20+ major CAD software packages or a neutral file format. The user views and prints the specifications, saves the application or requests a quote. This approach dramatically reduces the time and cost involved in designing and sourcing a linear system. It provides the opportunity for a company to focus its scarce engineering resources on its core competencies while taking advantage of the linear systems supplier's extensive experience.

Conclusion

In order to apply the correct type of linear motion technology in a particular application, the design engineer must consider the advantages and capabilities of each alternative. Selecting the right technology can reduce design complexity, improve performance and reduce the overall cost of the assembly. This article has explained how a new 360 degree engineering methodology can help OEMs create optimized design solutions for linear motion systems. The key attributes of the new approach include the avoidance of canned solutions, a robust product development process, use of modified or configured parts where practical, selection of suppliers capable of delivering complete systems rather than simply parts, and the use of online selection and configuration tools. This approach makes it possible to improve product performance while reducing time to market and engineering costs.