Why Motion Matters:

Exploring Motion and How It Affects Your Machine's Quality and Performance

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White Paper

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Engineers are juggling a lot these days. Many find themselves focusing on just getting a machine running so they can move on to other pressing matters at hand, but when it comes to Motion Control "good enough" just isn't good enough anymore.^

Your customers want a superior machine, no matter what it takes. Twenty or thirty years ago – when machine motion was commonly controlled by hydraulics, pneumatics and basic motor/drive systems – precision and performance took a back seat to basic machine functionality. But the game has changed.

New motion control technologies are enabling machines that are faster, more accurate and reliable, with quicker changeover and minimal downtime. To compete effectively, you have to make the technology and time investments necessary to design and deliver a superior machine, faster and at a lower total cost. Success depends on your ability to balance several competing dynamics:

- **Components versus systems.** Do you buy motors, controls, HMIs and other components from different suppliers and do the integration engineering yourself, or do you buy complete, modular systems backed by the expertise of a single supplier?
- **Performance versus simplicity.** If you do buy complete systems, your path to designing and building a machine is greatly simplified – but is there a cost in terms of machine performance? Could you do better with best-in-class components from multiple suppliers?
- **Optimized performance versus "good enough."** If you choose to make your machine as good as it can be, how do you respond to customer objections that another machine will do an adequate job for less money? Is optimized performance worth the higher acquisition cost, and if so how do you make that case to potential customers?
- **Outsourcing versus on-staff engineering.** When you buy complete systems, you're essentially outsourcing part of your engineering work to the supplier. Does it make more sense to pay a premium for the supplier's integration engineering and support, or to save those variable costs but keep more engineers on-staff at a fixed cost?
- **A focus on process expertise versus machine engineering.** How do you invest in human resources? Do you employ process experts? For example, in food processing, do you have one team that knows how to make an item, one that knows how to wrap it, and so on? Or do you focus on machine engineering and integration, adapting the processes to the machine's capabilities?
- **Cost versus performance.** For most customers, cost is the bottom line. Do you compete primarily based on the cost of your machine? Or do you offer solutions to drive greater throughput, reliability and overall equipment effectiveness (OEE) – solutions that may cost more initially but pay back the investment through increased productivity, accuracy and flexibility?
- **Work versus life.** Perfection isn't easy. Engineers at hundreds of companies like yours are moving at full speed to master motion at the levels of precision and performance today's market demands. But you shouldn't have to choose between a job well done and a life well lived.

Quality of motion plays a role in all these choices. "Good enough" is no way to build a machine, run a business or serve your customers.

Motion matters because it means building a better machine, bringing it to market faster, and improving functionality and supportability throughout its lifecycle. And that also means a more profitable business, a more satisfying career and even more time away from the machine to spend with the people and activities you enjoy.

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Beyond Acquisition: The True Cost and Return of Your Motion Choices

Why shouldn't you and your customers settle for "good enough"? Among many reasons, the most compelling is, paradoxically, cost.

While a less-capable machine may cost less to build and acquire, the advantage doesn't last long. If better motion can improve throughput by just 30 percent – a very reasonable goal – the ability to make more products, faster, drives down the per-piece costs of production. It also frees up production schedules to accommodate additional work, bringing in new revenues. Over time, increased throughput more than makes up for the initial cost of a better-engineered machine. Beyond that point, it's no longer a matter of recouping costs. As long as the machine remains in operation, it's generating higher profits. Increased throughput is just one cost advantage. Effective motion allows you to design a machine that does more. For example, through tight integration of multiple axes of motion, you can build a machine capable of performing more processes, so it can handle the specifications for more types of products. Motion can be used to automate changeover processes, so you can reduce changeover time from hours to minutes and save the wasted costs of downtime. Intelligent motion also allows you to design a more flexible and modular machine – one that can be easily repurposed to meet a variety of product requirements, and one that can grow to meet future requirements. More direct application of motion can eliminate gearboxes and other mechanical linkages, reducing maintenance and wear while shrinking the machine's footprint and lengthening its lifespan. Precise motion can reduce scrap by improving web handling and minimizing defects. Motion can even make a difference in operator safety by minimizing the probability of a dangerous failure and providing redundant systems for stopping the machine safely. Better motion control is also the key to making better products. Higher quality, greater throughput, less downtime for changeover and maintenance, more flexibility, reduced waste, minimal space requirements and a safer factory floor: When you add it all up, the best motion is the best value over the long term. As machine buyers and the customers for their products come to understand this, they're putting aside their notions of "good enough" and demanding the best. Engineers who respond to this demand gain a distinct marketplace advantage. And because better motion means less time installing, troubleshooting and maintaining machines, they also gain more time to develop next-generation machines that drive greater business profits and professional advancement.

Where Motion Matters: A Few Examples

Let's consider a few of the ways motion matters in daily operations on the factory floor. While motion defines every type of machine without exception, the following applications and processes highlight some of the most critical motion control issues OEMs and their customers face today.

Web Handling

Media used in printing, packaging and converting applications is becoming more diverse and often more fragile. One example is the emergence of biodegradable bags intended to reduce pressure on landfills and win sales from environmentally conscious consumers. As these fragile materials unspool and are fed through the machine, they need to be handled very gently and precisely in order to avoid stretching or tearing. Any flaw means wasted material and unproductive downtime. The ability to detect and instantly compensate for any deviations in the motion of the web becomes even more critical in high-speed production environments, where both the chances and consequences of material failure increase exponentially.

Registration

Accurate registration is essential to high-quality printing and packaging. It's a challenge to precisely detect registration marks on a web that's traveling 2,000 feet per minute or more, and to continuously position a servomotor in relation to those points. If the registration is off, you waste a lot of material. A test run is needed to make sure it's right – and a shorter test run means less material used and a lower cost. Precise motion control for better accuracy and high speed registration makes it possible to test more quickly and reliably, and also to hold registration accuracy throughout the production run.

Wrapping

Consumers used to accept wrinkled wrapping and misaligned labels on irregularly shaped products, such as frozen poultry. No more. If the packaging quality is poor, they'll assume that the product inside is too and they'll move on to the competition's offering. Keeping consistent web tension at a high speed – while constantly adjusting for variations in product size and shape – requires very accurate motors and gearing along with a control system that provides enough bandwidth to respond nearly instantaneously to the machine's feedback mechanisms.

Flying Shears and Seals

Similar to printing applications, flying shears, perforators, seals and other processes that are applied to material in constant motion rely on precise registration of the material to the position of the device. These applications also require accurate speed matching between axes, as well as high-bandwidth feedback to enable the control system to adjust for even the smallest deviations. Mismatched inertia, backlash in the mechanical transmission systems, or inadequate bandwidth in the control system can all contribute to unacceptable product quality and waste.

Incremental Motion

The examples we've looked at so far involve constant motion. Many other applications – such as a sheet-fed printing machine or a punchpress – require incremental motion. When dealing with paper, corrugated paperboard, steel, tile or other material in individual pieces rather than a continuous web, the machine needs to rapidly accelerate each piece into position, allow time for it to settle in place, apply the process, and then

rapidly accelerate the piece out for the next process. The time spent in motion by each piece is unproductive time. In other words, the faster you can move individual pieces in and out of each process, the more times per minute you can apply the process that adds value. Precise motors and drives coupled with high-bandwidth controls allow parts to be accelerated rapidly yet gently into position without damaging the material.

Medical Imaging

We've mainly been discussing printing, packaging and converting applications, since motion control is so fundamental to productivity and quality in these industries. But motion is virtually everywhere, and better motion is often the chief requirement for market success. Medical imaging is just one example.

CT scanning machines require precise motion control for high-inertia loads. Any velocity ripple in the system causes blurring of the images, so motors, drives and controls need to be selected for the smoothest possible operation. Patient comfort is also an issue, and quieter motors help minimize the noise patients are subjected to while in the machine. Electrical noise must also be kept to an absolute minimum to protect sensitive electronic equipment used throughout the healthcare environment.

Other industries that depend on superior motion control for their most critical processes include electronics assembly, semiconductor manufacturing, parts assembly, the machine tool industry, the automotive industry and several others. While the end products differ, the motion control requirements are basically the same. Better motion means better productivity for better products.

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Making Motion Better

Making motion better isn't necessarily easy. You can't just buy a better component or write a better control program and expect the best results. Taking a machine from "good enough" to best-in-class requires a total-system approach to machine engineering.

For example, optimizing a single axis of motion requires sizing the motor appropriately for the load's inertia and range of motion, choosing drives and mechanical components capable of providing the precision you need, choosing controls with the bandwidth and responsiveness to correct for any limitations in the mechanics, using the right software, and so on. It's all connected.

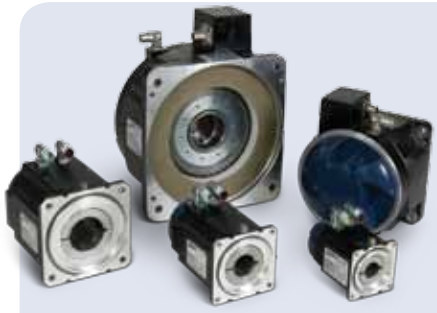
The interconnections become even more critical when coordinating that single axis with all the other parts of the machine, or when coordinating multiple machines across the factory floor. The goal is to build machines that maximize Overall Equipment Effectiveness (OEE) while producing more kinds of products, in appropriately sized runs, with minimal changeover and maintenance time.

Better motion – and better coordination of motion – allows machines to do more, with higher throughput, less downtime and more versatility. We've already discussed some of the reasons why – such as higher speeds, less scrap and reduced maintenance thanks to better motion at the component level. The following sections will look beyond the motion of individual machine axes to consider some of the ways motion can improve entire manufacturing systems for greater OEE and versatility.

Coordination Between Axes

Engineers have a term for the function of yesterday's rudimentary control systems: "bang-bang" – meaning that the system is either on or it's off. Optimum performance requires much more fine-tuned control than that. Like an orchestra conductor, a machine's control system needs to get everything on the machine moving in perfect synchronization. For operations that require subtlety and gentleness of motion in addition to speed, "bang-bang" simply won't do.

To improve OEE, the control platform should be regarded as the nerve center of the entire system, not simply another component. Controls and their servo drives need the bandwidth to overcome compliance, resonance, friction and other issues in the machine hardware – with position, velocity and torque loop updates measured in terms of microseconds or even nanoseconds. And because electronic gearing is much more precise and responsive than mechanical gearing, the best systems will incorporate controls that orchestrate total machine motion, not just individual components. That requires even greater bandwidth, as well as very sophisticated control software.



Cartridge Direct Drive Rotary™ (DDR) Motor Series

Direct Drive Technology Enhances Precision and Performance

Direct drive technology increases bandwidth by eliminating the mechanical transmission components responsible for most compliance issues, while providing better than 1 arc-second repeatability. Sixty times more accurate than a conventional motor/gearhead – while requiring fewer parts, zero maintenance and no need for inertia matching – direct drive technology is the preferred choice for applications where motion truly matters.

Product Flexibility and Changeover Time

Changing over a machine to make a different product used to mean cutting all power to the machine and going in with wrenches to adjust machine parts – a process that can take hours and is fraught with the potential for slight inaccuracies and outright mistakes. Through better motion control, the changeover process can be largely automated, reducing the time required from hours to minutes.

Automated machine setup and changeover can also make it easier to support shorter runs of a wider range of products, providing a much more flexible response to market needs at any given time. And because inertial loads may vary considerably from one product to another, machines that can adapt to these differences through better motion control can manufacture a greater variety of products to capture higher revenues.

One-Piece Flow

Most packaging machines in service today are multiple-stage machines. A machine that forms boxes might, for example, process 4, 6 or 8 boxes in parallel. In an emerging trend, some manufacturers are moving to machines that produce one product at a time.

This one-piece flow allows operators to detect and correct bad products faster, reducing waste. It also provides better inventory control and more flexible machine scheduling to accommodate rising and falling demand. And if you can get the same production rate as the old multiple-stage machine, you can double throughput (not to mention plant flexibility) simply by adding another machine.

For this one-piece flow strategy to work, manufacturers need machines that perform much faster in a smaller footprint compared to multi-stage machines. And the need for smaller and faster machines can only be met through better motion control. Correctly sized motors, elimination of unnecessary mechanical linkages, high-performance electronics and co-engineering application expertise all play a role.

Modularity and Flexibility

A more capable machine is one that adapts to different requirements, today and tomorrow. By making machines more modular, OEMs can build in adaptability to suit the needs of different customers. For example, one customer may need a perforation unit in a packaging machine while another customer may not. Controller software that's written in a modular fashion can automatically turn the perforation function on or off based on whether or not the unit is installed in the machine.

Modularity can also make it easier for customers to adapt the machine to a variety of purposes. For example, a machine may incorporate a complex series of axes to process raw material into a finished product, as well as a simpler system for outfeeding, stacking and packaging the finished product. Instead of building one big machine, the outfeed function can be designed as an independent module with a secondary control system that's slave to the main controller. This gives customers the ability to use the outfeed module on one production line today, then roll it down the factory floor to use it on another line tomorrow. A common control platform across all control, feedback and drive devices – coupled with a standards-based connectivity protocol such as Ethernet – is essential to support this modularity.

There's also a trend away from centralized control and drive systems cabled to the machine, and toward integrating these components together and placing them on the machine itself. This allows greater versatility while saving floor space, reducing the need for expensive cables and simplifying the manufacturing environment. Integrated electronics mounted directly on the servomotor also simplify maintenance, reducing parts inventory and allowing replacement of a single component – although a somewhat more expensive one – in the event of a malfunction.

While this approach lowers the cost of cabling, it requires suppliers to design and build motor housings capable of shielding the electronics against the corrosive atmospheres, hose-down requirements and other harsh conditions of the factory floor. In addition, motor/drive performance output is typically de-rated to compensate for the higher temperature of the combined assembly. Given these constraints, having the experience and expertise to co-engineer the optimum solution for a specific machine architecture becomes critical.

Connectivity Across Manufacturing Processes

When all machine components use the same control architecture, the same programming environment and the same connectivity protocol, it's much easier to build a machine that offers modular flexibility along with perfectly coordinated motion in any configuration. This same principle can be applied across the factory, allowing all machines to communicate with a central monitoring, reporting and control system.

The more useful information that can be reported upstream – and the faster it can be reported – the more productive the factory can be. That includes information about production status, throughput, developing faults, troubleshooting information and more. To cite just one example, a change in the current draw of a drive may indicate that a bearing or linkage is causing undue friction and may be about to fail. If that information is reported to a central monitoring system, the parts can be scheduled for inspection and possible replacement during a normal break in production – avoiding the waste, downtime and potential safety issues of a failure during the production run.

Standardizing control and communications methods across the factory is the first step toward centralized monitoring and control. Complementing the trend toward moving electronics closer to the axes they control, wireless communications can be used to report status upstream to a centralized monitoring and reporting system. As wireless systems prove their reliability, they'll increasingly be used for control systems as well, enabling centralized control of an automated factory with unprecedented flexibility.

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At Kollmorgen, everything we do is driven by one overriding principle: motion matters. It matters in every part of the machine, in the coordination of parts throughout the machine, and in the coordination of machines across the factory. It matters in printing, packaging, converting, healthcare, defense, commercial vehicles, energy generation, order picking, elevators, electronics assembly and a host of other industries and applications.

We're a one-stop supplier for total machine automation that provides the industry's highest bandwidth, fastest response times and simplest usability. Kollmorgen invented direct drive technology, and nearly 70 years later we're still the direct drive leader. We work relentlessly to bring new motion innovations to market, such as our new Cartridge Direct Drive Rotary™ (DDR) motors that combine the performance advantages of a frameless direct drive motor with the ease of installation of a full-frame motor.

Our AKD™ family of servo drives provides a global platform for applications requiring up to 50kW of output power. With its patent-pending auto-tuning, easy-to-use graphical interface available in multiple languages, and the ability to drive all motor/feedback types, the AKD platform sets a new standard in high-performance motion control. As a core feature of the performance engine, 670-nanosecond current loops provide ample bandwidth to suit the needs of even the most demanding applications. And because a single drive interface is used across the product line, AKD significantly reduces global costs for spare parts and training.

Also our Kollmorgen Automation Suite™ (KAS) is a complete, integrated set of software tools and hardware components designed to accelerate the development of high-performance machines. Its pre-integrated components and easy-to-use rapid software development tools help you bring better machines to market faster and more affordably. Using KAS, you can create machines that produce the highest-quality end products with optimum throughput, minimal waste and outstanding OEE.

In addition to these new innovations, we offer a complete line of servo and stepper motors, drives, gearheads, linear positioners and more. With Kollmorgen, you can get literally everything you need – all designed and optimized to work together – from a single supplier.

And not just any supplier. Our global footprint includes centers of engineering excellence in every major region of the world. Flexible manufacturing facilities in North America, Europe and Asia ensure continuity, affordability and timeliness. Our global supply chain speeds time to market and reduces risk, while our global support teams are there for you anytime, anywhere. We've been the motion leader for decades, and with our financial and organizational strength, you can count on Kollmorgen standing behind you and your machines for decades to come.

Our greatest strength and satisfaction is solving your motion problems, no matter how difficult. Whether you need a standard solution, a custom build, rapid development tools to build your own solution, or support to keep your machines productive and profitable throughout their lifecycle, Kollmorgen means the difference between a commodity product and true differentiation for your machine. That's why we hope you'll choose Kollmorgen. Because Motion Matters™.

To learn more about how Kollmorgen solutions and co-engineering can improve the motion of your machine, **contact us at: (540) 633-3545 or support@kollmorgen.com.**