Drive & Control
profile

Technical Article

How Adaptive Systems unlock big productivity gains

Rexroth Adaptive Systems technology in IndraMotion MLD motion controllers provides the intelligence to apply vibration damping and avoiding control methods, which can increase throughput and extend machine life in processes where sloshing, vibration and sway cause problems.

In this article, helpful insights regarding:

- Identifying applications where vibration control can boost throughput
- Understanding how oscillations occur—and can be controlled
- Determining the technologies needed to control slosh, vibration and sway

offers the next big opportunity for productivity gains in manufacturing. Rexroth addresses this with Adaptive Systems motion-control technology that reduces oscillations in a wide range of applications. Increases in process throughput by as much as 50% are possible.

Increase throughput up to 50% with Rexroth Adaptive Systems technology

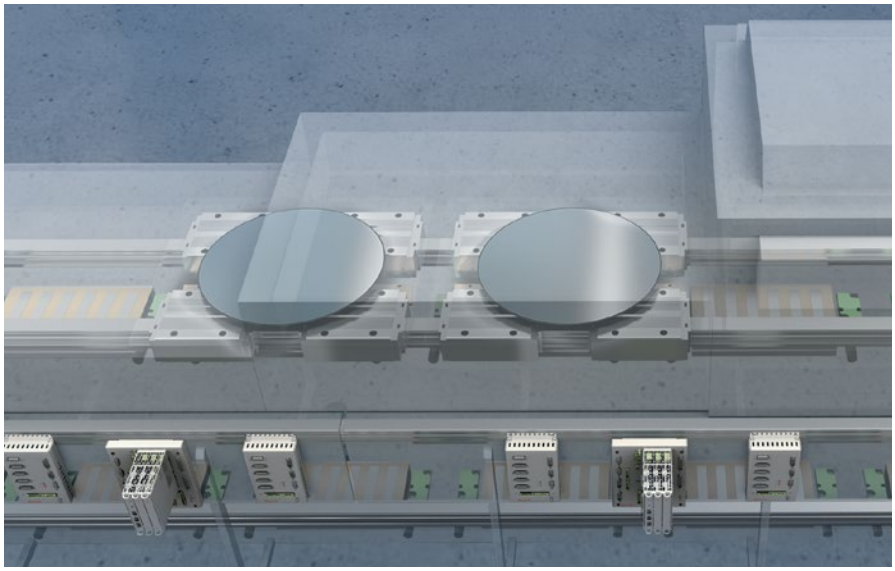
Increasing the speed of a packaging line, a machine tool or a pick-and-place operation may seem like an easy way to boost throughput—until unwanted vibration (either induced or parasitic) requires deceleration to avoid damaging the machine or product. With modern materials and mechanical engineering concepts, the inherent speed of machine movement is often not the limiting factor for throughput. Rather the time required for the product to settle or for the machine to stabilize after a move limits the rate of production. Controlling these unwanted movements (oscillations/vibrations)

Controlling oscillation improves productivity

Liquids that oscillate inside moving packages, and objects that vibrate or sway as they are transported by a machine tool or robot arm, are common industrial problems. However, when the proper solution is applied to control oscillation, the gains in productivity can be dramatic.

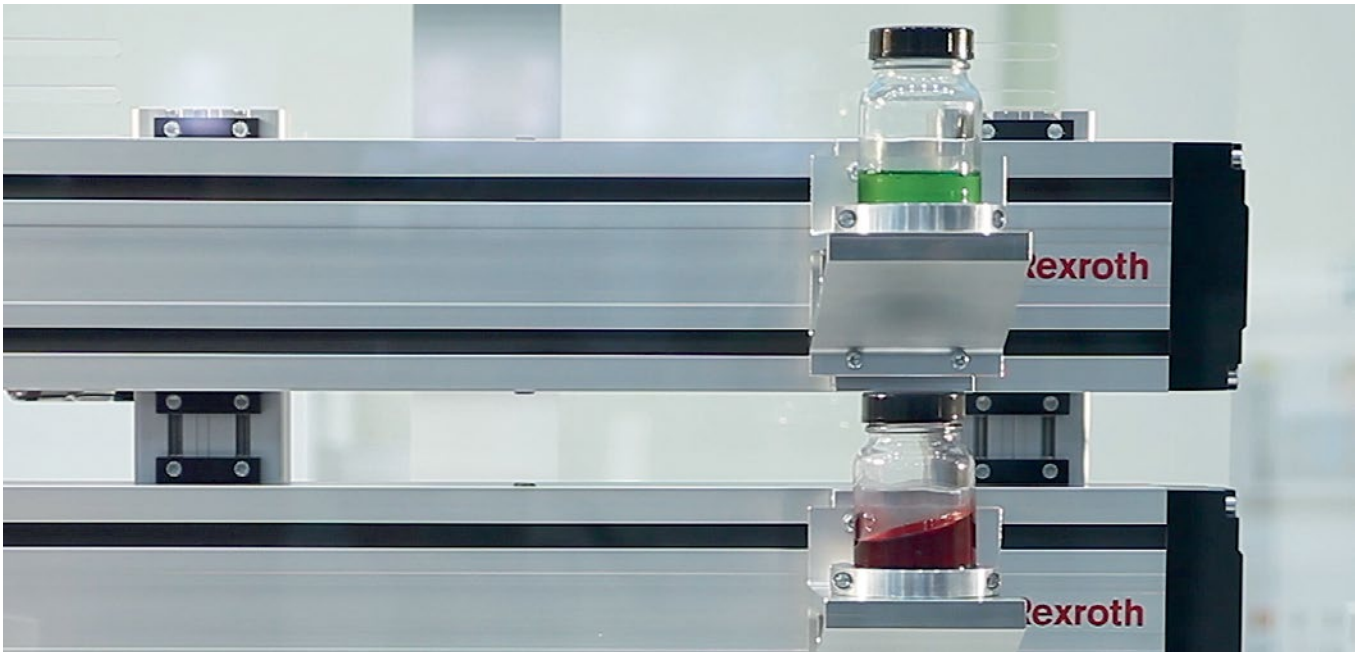
Benefits of controlling vibration
With a machine tool or a robot arm, vibration can be imparted to the object by movement of the object itself, as well as by machine resonance—the low-frequency hum or ringing inherent in mechanical systems. Vibration impacts product quality as well as throughput. Longer transient times to dampen oscillations reduce productivity, while quality and dimensional accuracy are limited by the mechanical effect of the oscillations.

When a mechanical system resonates, the frequencies can be captured by the intelligent drive system. Damping and avoiding functions can then be introduced to reduce resonance. Less vibration not only reduces dimensional variation and damage to the product, but also permits shorter stabilization and transient times to increase machine throughput. In addition, reducing vibration reduces mechanical stress, which extends machine life. Applications where vibration is an issue include wafer handling, certain pick-and-place applications, printing and converting operations, and CNC operations. Machine tools and robots where vibration damping and filtering are implemented typically realize 10% to 50% higher throughput.



Controlling vibration can improve quality and yield when handling fragile or sensitive components, such as semiconductor wafers.

Benefits of controlling slosh
With packaging that contains fluid, acceleration or deceleration of the package induces motion—or slosh—in the liquid. Sloshing liquid negatively affects folding, filling, sealing and measuring processes. More reserve



Controlling slosh can improve throughput in a bottle filling line.

space in the container, more wait time for the contents to settle and extra space to allow for package movement are commonly required in liquid handling applications.

Because package movement is controlled by servo drives, using adaptive technology to minimize slosh provides several benefits. It reduces reserve space required in the container, which allows container height to be lowered to reduce the amount and expense of packaging material. Greater stability in the fluid meniscus also allows the use of optical level sensors to provide feedback to further optimize motion control.

In the process, anti-slosh technology shortens stabilization times, which cuts down on the transient time needed to allow contents to settle. The result is faster filling and sealing rates and machine cycle times. Applications where slosh prevention is particularly beneficial include packaging lines for beverages, pharmaceuticals, oils and chemicals. Packaging lines that implement anti-slosh motion control typically see improvements in throughput from 10% to 50%.

Benefits of controlling sway

For cranes or gantry robots, acceleration or deceleration of a trolley or robot carriage from which a load is suspended by a cable or arm will cause the load to sway. Sway makes it difficult to position the load over the target area, which slows down operations. The load behaves like a pendulum that oscillates over the target position, requiring operators to delay the operation or introduce a compensating motion until the load settles.

Controlling sway can speed up positioning when handling a suspended load.

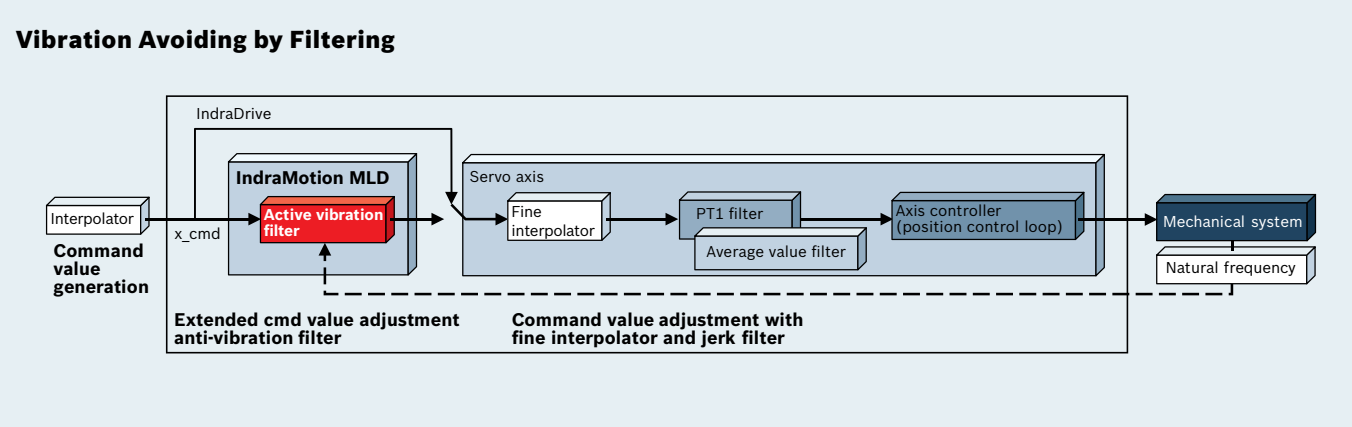
A motion control system that dampens sway not only enables faster, more accurate positioning, but it also allows the end-effector to more rapidly engage or disengage the product. An anti-sway motion control system that can adapt to changes in the mechanics and load will further reduce physical stress on the product and allow increased process speeds. Wear on the mechanics, bearings and frames is also reduced. Smaller size motors can be used, which reduces energy consumption. Applications where sway is a factor include pick-and-place operations, material transfer and warehouses, and assembly lines. Implementing anti-sway technology can improve productivity by 20% to 40%, which translates to increasing picks from 30 to 45 picks per minute.

Why oscillation occurs and how it can be controlled

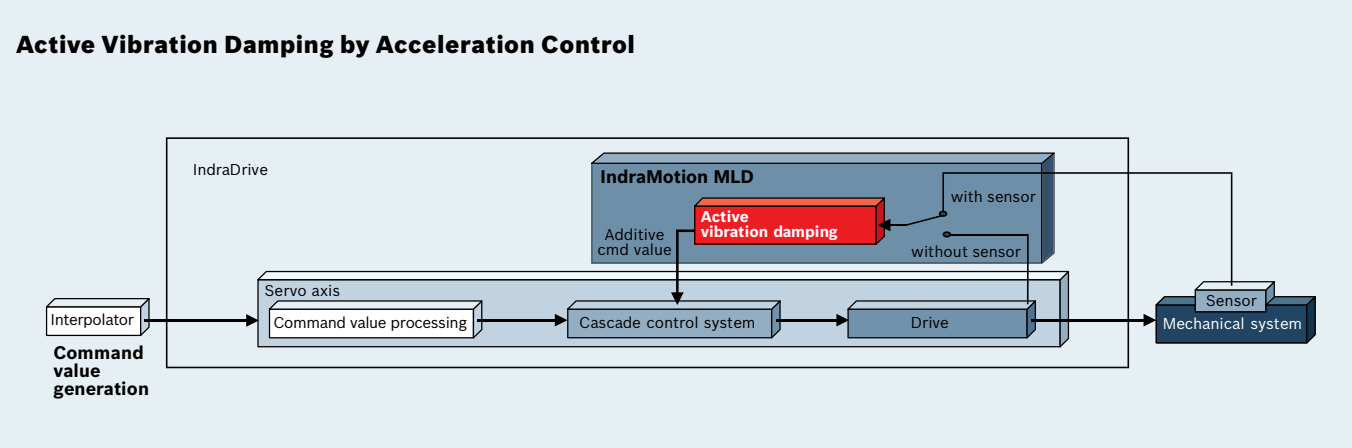
Vibrations or oscillations are simply motions that repeat over a period of time. Controlling slosh, vibration and sway involves factors of wave physics. Oscillating waves in industrial machinery typically take the form of asymmetrical sinusoidal waves that vary in amplitude and frequency.

Oscillations can be classified as free vibrations, in which objects (like a tuning fork) vibrate on their own after an initial disturbance to the system, and as forced vibrations, in which objects (like an out of balance washing machine) vibrate when an external force disturbs the system.

Oscillations that occur as smooth sinusoidal harmonic waves can be



Open-loop control used in vibration avoidance employs frequency filtering to enable the motion controller to send position commands to cancel vibration.



Closed-loop control used in active vibration damping employs feedback interpolation and external inputs to send force or acceleration signals to cancel vibrations.

further classified as linear vibrations, which are typically observed in small amplitude vibrations of flexible shafts and long, slender objects, and as non-linear vibrations that are distorted sinusoidal waves propagated by interactions between the object being manipulated by a machine and the internal resonance of the machine itself. Machine resonance can take the form of a “white noise” hum or frequency between 5 to 40 Hz.

The complex physics of waves often make traditional methods of controlling oscillations ineffective. For example, adding stiffness or mass to increase machine bulk can help reduce vibration, but it is costly and cannot completely eliminate machine resonance caused by servo drives and other components.

Increasing time to allow contents or objects to settle is a simple tactic that allows wave energy to disperse, but from a production standpoint, causes waste in the form of waiting time.

Vibrations can be minimized by smoothing the motion with jerk-limitation or S-curve motion control profiles to avoid abrupt acceleration or deceleration. But programming can be complex and can accomplish only a limited amount of correction. Too much limiting to create smoother motion will slow acceleration to the point that machine cycles are reduced, further limiting productivity.

Software-based motion control: The smart way to get vibrations under control

The alternative to increasing physical bulk or transient time is to use a

software-based motion control that can settle or filter vibration by adapting to changes in the material, the load and the environment. To control oscillations, motion control programs can utilize two techniques: avoiding and damping. Avoiding technology filters the vibrations caused by high dynamic movements. Damping technology uses external feedback to employ counter-acting kinetic energy to settle vibration. This feedback can be provided by the motor, an external encoder, or an accelerometer.

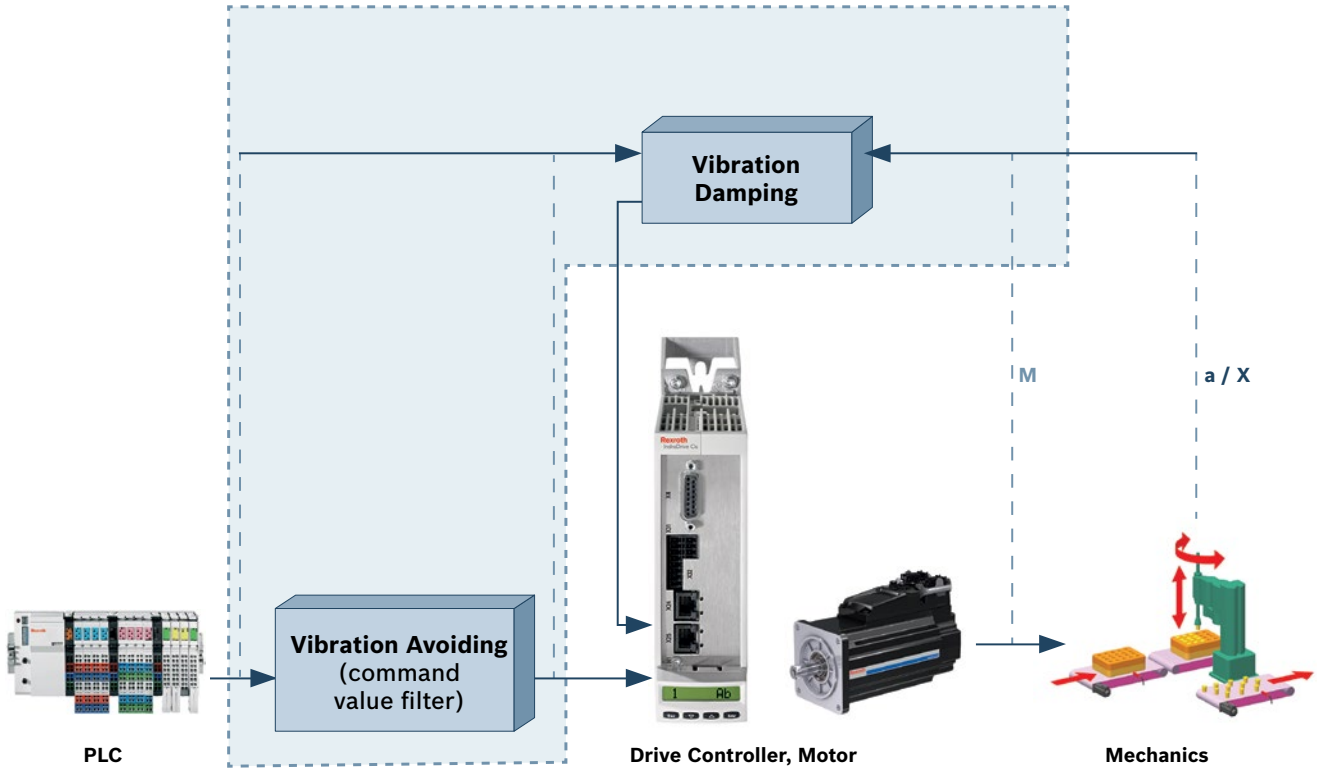
These techniques are accomplished by mathematically modeling and applying the appropriate value to the control system of the servo axis. These functions require high intelligence and rapid processing in the motion controller.

Vibration damping and avoiding functions can be used wherever low-frequency vibrations are propagated in a machine or its end-effector due to the mechanical structure or the ambient conditions. Different control loop configurations are used depending on the design and the work flow of the machine.

With vibration avoidance by filtering, open-loop control is used without external feedback. The resonance frequency mode of the system is modeled, so all that is required is for the motion controller to send position commands to cancel vibration. This is different from merely doing an S-curve or jerk limiting to the motion profile. In application, this technique is particularly suitable for a one cell system where an object is locked into a tool with no load changes.

With active vibration damping, closed-loop control is employed with a position interpolator and sensor feedback to send force or acceleration signals to the motion controller. Then the drive generates the torque position or velocity offset to cancel the vibration and suppress externally induced vibrations. A self-tuning, proportional-integral-derivative (PID) controller using adaptive intelligences adjusts the drive based on interaction with the machine and the load. Consequently in application, this technique is suitable for machines handling changing loads.

The two techniques—both vibration avoiding and vibration damping—can also be implemented together, which is currently unique to Rexroth.



A Rexroth drive system with Adaptive System technology can implement vibration damping and avoiding together with or without a PLC.

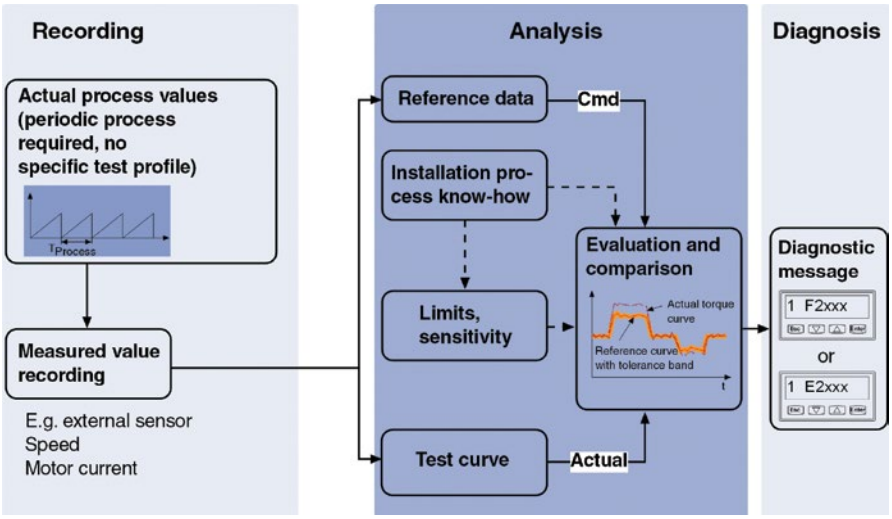
Rexroth delivers Adaptive System advantages from commissioning to predictive maintenance

Because implementing vibration damping and avoiding techniques requires a control system that can quickly adapt to varying process, material and application changes, Rexroth employs Adaptive System technology at the drive level, rather than at the higher control level.

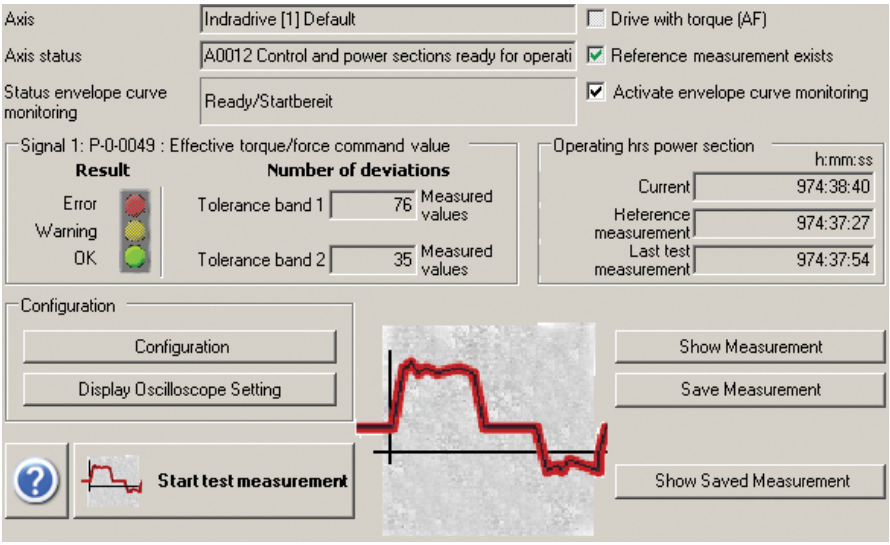
Providing the motion logic and command value processing at the drive level speeds up event handling and avoids the delays inherent in a control system's cycle and update times.

Rexroth Adaptive System motion control can handle high-speed inputs and deterministic events with closed-loop response times that are unsurpassed by any other solution. For example, current closure can be accomplished in 62.5 microseconds, speed loop closure in 125 microseconds and position closure in 250 microseconds.

Drive-based firmware also allows more flexibility in implementation. Rexroth offers firmware options that provide base performance and high-precision performance. The user can select the option that fits their application and pay only for the features that achieve their required level of performance.



Envelope Curve Monitoring allows you to analyze and diagnose a variety of configurable signal measurements based on tolerance levels defined by the user.



When Envelope Curve Monitoring is loaded to an axis using Rexroth's IndraWorks software, the user interface simplifies the process to visualize and configure the two defined tolerance bands.

If other high-speed functions are required—such as event capturing, inputs or precision motion—they can also be added affordably.

Drive-based Rexroth Adaptive System technology provides a unique double benefit: Where the application encounters induced or parasitic vibrations in the machine, open-loop vibration avoidance can be implemented as standard on the drive; when encountering non-linear, non-repeating disturbances, closed-loop vibration dampening can easily be added. It's a flexible solution that can be combined as needed for maximum control, stability and affordability.

Implemented in Rexroth IndraMotion MLD drives with the IndraWorks engineering framework

Rexroth Adaptive Systems technology is implemented in our IndraMotion MLD drive-based motion logic controller. This platform provides complete support for all Adaptive System component technologies. The solution includes: Rexroth IndraDrive

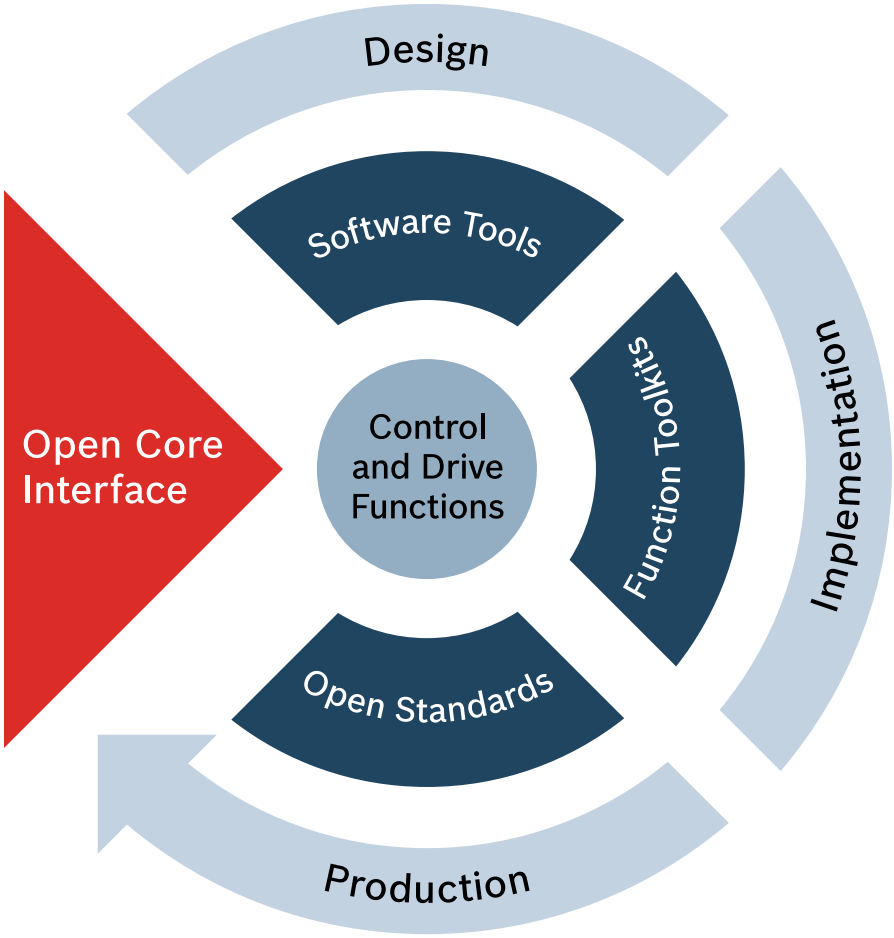
drives with sensors that monitor the status of axis mechanics, as well as Rexroth Productivity Agent monitoring and mechanical analysis software.

Productivity Agent uses drives as intelligent sensors to monitor, analyze and reduce vibrations in real time. This is accomplished with algorithms that make control parameter adjustments dynamically, which are then translated by the controller into damping or avoiding commands.

Within the IndraWorks environment, setting up the Productivity Agent for a particular application is easy. IndraWorks loads the Productivity Agent into the drives. Parameters are set and run through IndraWorks dialogs. The dialog-based environment minimizes tweaks and commissioning/tuning time. For example, there is no need to configure the base kinematics for oscillation-compensating motion; the user can just plug in parameter values without doing any programming.

In addition to enabling damping and avoiding functions, the powerful data monitoring and mechanical analysis of the Productivity Agent provides predictive maintenance capabilities. Once tolerance thresholds and sensitivity parameters have been established for the specific application, the Productivity Agent will immediately notify the user if thresholds are exceeded. This gives the user early warning of problems before premature wear occurs or the machine fails.

The Productivity Agent monitors any signal (e.g., torque or position) during the entire production cycle and analyzes it in terms of defined tolerance thresholds for the operating envelope. In fact, envelope-curve monitoring is accessible online, allowing the operator to conduct frequency response and mechanical analysis to make adjustments and respond to problem alerts based on pre-set thresholds.



With the Open Core Interface, users enjoy unparalleled flexibility for device platform selection, PLC programming and high-level language integration, including libraries for LabVIEW, the graphical programming platform.

Development for specific applications is simplified by Rexroth Open Core Engineering, an automation software and programming platform that allows personnel unfamiliar with PLC/HMI programming to create automation applications. This development environment provides the software tools, function modules, libraries and support that allow programmers who know C++, Java and other high-level languages to translate the application into ladder logic for motion control.

The Open Core Interface also provides libraries for LabVIEW—the popular graphical programming platform—to provide data acquisition on a Rexroth HMI to eliminate the expense of using a separate PC.

Open Core Engineering tools combined with the Productivity Agent make it easy to access runtime data and predictive information, allowing operations to detect problems and take corrective action before a

machine fails or production targets are missed. As an example, information could be sent to a plant manager's smart phone. Rexroth offers sample apps, such as Machine Diagnostics, to further help programmers leverage the power of Open Core Engineering.

With Productivity Agent software tools and the Open Core Engineering development environment, Rexroth Adaptive Systems technology can be employed in a wide-range of applications: from individual single-axis machines to entire production lines—including form and fill systems, fill and seal machines, multi-packing machines, pick-and-place robots, high accuracy assembly operations and wafer handling.

As the only drive-based adaptive motion control solution that handles both open-loop and closed-loop oscillation control in real time, Rexroth Adaptive Systems technology fully harnesses the intelligence of IndraMotion MLD motion logic controllers and IndraDrive servo drives. The result is an easy-to-implement vibration damping and avoiding solution with a predictive maintenance capability that can dramatically increase productivity now—while making the process run smoother and quieter with longer-lasting equipment life for the future.

To find out more or request a consultation, please visit www.boschrexroth-us.com/productivity.

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