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Machine, Heal Thyself: Improving Packaging Machine Productivity with Drive-Based Predictive Maintenance

Human protective reflexes are triggered by the central nervous system, bypassing conscious thought and operating with extraordinary speed. This distributed "nervous system" concept can be transferred to automation: integrating diagnostics and predictive maintenance functions into the drive control gives packaging machines the ability to detect and prevent mechanical problems at an early stage before a costly breakdown.

In recent years, modern pharmaceutical packaging machines have become ever more intelligent, and in some ways also more "human." They are incorporating more decentralized intelligence in order to utilize, as humans do, a comprehensive nervous system. For machines, that means sensors. With decentralized intelligence, it is possible to protect the machine from expensive breakdown situations using quick reflexes (error diagnostics and reactions) without any detour through the control.

With today's generation of intelligent servo drives, *predictive maintenance* functionality is now built into the electronics. Predictive maintenance monitors machine performance and maintenance thresholds (the "nerves"), providing drive-based automated diagnostic and motion control functions that protect the machine throughout its entire life cycle (the "reflexes".)

For pharmaceutical and healthcare packaging operations, predictive maintenance can prove highly valuable. The industry demands high levels of machine reliability, availability, throughput and packaging precision. Operations that package pharmaceuticals, surgical instruments and medical devices (pacemakers, earphones, etc.) are typically optimized for 24/7 operation.

The products themselves have a high-dollar value, so extremely accurate, low-waste, high-throughput packaging is standard practice. In this environment, if machines require frequent adjustment and constant, disruptive repair work, they waste time and money.

Predictive maintenance helps prevent this, through an approach built around early detection and healing of “machine illnesses.” If damage is developing inside the machine, similar to illnesses or injuries in people, drive-based intelligent functions detect the problem early and appropriate remedies are implemented before significant damage occurs, frequently on an automatic, or “self-healing” basis.

Immediate Protection for Drives and Axes

A wide range of pharmaceutical packaging machines can benefit from predictive maintenance. This includes vial-filling machines for liquid injectable medications, capsule filling machines and blister packaging for solid medicines, and tray packing, cartoning and case-packing machines for surgical kits, medical devices and other products.

Drive-based predictive maintenance works best by streamlining the information exchange between the packaging machine controller and the drive actuators/sensors. That’s why optimizing data exchange between the drive and control is given a high priority during the development of a predictive maintenance system.

Drive-based predictive maintenance can monitor mechanical characteristics such as backlash, belt stiffness, tension, load variation and other conditions that are critical to the packaging machine’s operation. The intelligent drive monitors itself *and* the feedback it gets from the motor it is driving: motor torque, speed, acceleration and other parameters can be tracked. If these characteristics fall outside of the tolerance bands for that axis, the drive recognizes that something is wrong, and takes the appropriate action – the same way our reflexes "automate" our response if we bang our knee or touch a hot stove.

To keep the data exchange between the drive and its control to a minimum, the performance thresholds are pre-set in the drive and fixed corresponding target values are transmitted to the controller. For example: In a liquid filling machine, 10 vials are being moved down a single conveyor and need to be positioned under 10 nozzles for filling. The machine lowers the nozzles into the containers, fills them, then lifts them out and re-positions the nozzles for the next set of 10 vials. This highly repetitive "walking beam" motion sequence – down to fill, over to the right, up, back to the left, down – has extremely tight tolerances for accuracy and throughput.

If a belt on the conveyor or a gearbox on the filler axis slips, machine synchronization is lost – which could lead to a crash, or improper filling, leading to wasted product. Since this slippage affects motor performance, and the drive detects the variations in the pre-set values, the deviations can then be used for monitoring or analysis of the axis.

Preventing "fatal" errors – before they "kill"

Not all reactions of a machine or a human being can be left to the control or the brain. If the brain were responsible for the appropriate response to touching a hot stove, this would occur with such a delay that there would not be sufficient protection from burns. To prevent this, the flinch response bypasses the brain in a so-called reflex circuit.

It is exactly the same in automation. The detection of a fatal error in the drive must lead to the proper reaction *at the drive*. For the electric drive itself, this is the current state of technology. With predictive maintenance, this protection is extended further to the connected axis mechanics, where additional "reflexes" have been included to protect the mechanical system or the entire axis.

Again, consider the vial-filling line. Once the vial is filled and capped, a pick and place application inserts the vial into a container, along with a pamphlet containing prescribing information for the physician. If there is a jam-up in the carton loading – the pamphlet insertion gets out of synch with the vial insertion – the vial or the carton could be damaged, forcing a shutdown of the cartoner.

Drive-based predictive maintenance can prevent these slips from growing into significant problems. It does this by monitoring the backlash between the servomotor and the axis mechanics the motor moves. The performance of the motor is directly related to the performance of the mechanics the motor moves. The drive monitors how the motor responds to the amount of play in the gears or the belt; if it falls outside the tolerances you set for that axis, the drive intelligence can do one of several things:

- Generate a warning message to the controller or operator
- Modify the drive current to compensate for the change in the mechanics
- Initiate a safe shutdown, to prevent machine and product damage *before* the situation gets critical.

Reflexes like breathing mean the preservation of life for humans. Similarly, a servomotor will not turn or fulfill its intended function if drives did not have something like reflexes. Intelligent drives, such as the Rexroth IndraDrive can stabilize the disturbance [noise] of all types using the control loops found in the drive. Quick and direct real-time access to all drive parameters is what makes faster reflexes possible.

Sometimes, a reaction in the drive can be triggered by multiple "unhealthy" or risky conditions. These can include an extreme condition signal, like setting an input or initiating a command -- a reverse movement after a collision, for example -- or the targeted initialization of an analysis function in the drive to detect the detailed axis status.

Similar to the human nervous system, complex information is prepared in the drive and translated into a simple diagnostic for the controller; this replaces sending all the complex information to the controller, and taxing cycle times to have the PLC do the diagnosis. It's a more efficient controls architecture, since the communication required between the control and the axes is automatically reduced.

Prediction depends on extended diagnostics

Even machines can feel "ill." Then, they act like people; they diminish their productivity until reaching a complete breakdown. And like humans, proper care, ("an apple a day, etc.") on a regular basis, is the best medicine for long-term machine health and productivity.

Wear-related machine breakdowns make themselves known ahead of time, and extended diagnostics makes preventive measures possible. With its IndraDrive, Rexroth has structured preventive maintenance into three key diagnostic functions:

- Maintenance Planner: Tracks time-specific maintenance intervals defined in the drive, to issue a warning, remind about upcoming maintenance activities or execute a self-analysis.

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- Monitoring Function: provides expanded diagnostics, runs during operation and enables constant monitoring of the total axis status, including the attached mechanics. It can also indicate a subsequent system analysis that needs to be performed.
- Analysis Function: Expanded mechanical analysis and comparison with "zero-hour-record" -- the performance tolerances set in the machine at start-up. In a separate test run, while using expanded analysis methods, a correlation between the error location and cause can often be determined.

In our cartoning example, a motor is hooked up to a belt, which drives a pusher loading the vial and pamphlet into the package. The belt is a toothed belt, run on a toothed gear driven by a servomotor. If excess wear and tear, or high accelerations, or poor lubrication causes a tooth to jump on the belt, the vial and pamphlet won't be fully inserted in the package – setting up a potential jam situation.

On this machine, using extended diagnostics:

- The Maintenance Planner has a pre-set schedule calling for maintenance of belt tension every 100 hours;
- The Monitor Function will be set to monitor belt stiffness, based on motor feedback, to detect if a belt is getting loose;
- And the Analysis Function compares that axis' performance to the zero hour record in the drive; if it falls outside the tolerance band for that motor, the situation calls for maintenance intervention to protect the machine and production.

Diagnostic messages can be displayed on the drive display, PC, control or handheld units. To keep the communication requirement as low as possible while continuing to transmit the established standard communication mechanisms, the information related to signal processing is taken care of in the drive and therefore highly compressed.

"Zero Hour" Baseline Crucial to Predictive Maintenance

People who are concerned about maintaining good health usually get a yearly checkup – not because anything is wrong, but by having an annual baseline of their health, if an illness or chronic condition begins to develop, it can be checked against their original condition.

The same principle is true for machine "health." Drive-based predictive maintenance must be built on capturing and loading into the drives the optimal performance of each axis at it's healthiest: "zero hour" when the machine is completed commissioning, but before it's released for production.

Some tool builders and manufacturers hesitate to invest the time and effort to accomplish this – but it is investment that will protect machine performance and practically guarantees to extend the machine's operating "life."

This investment is especially valuable for synchronized multi-axis lines. For example: in a robotic pick and place application – for example, placing needles in a tray –12 robots operate over a single conveyor (a row of six robots on both sides of a conveyor.) Each robot is assigned an operating zone; if one robot slips a gear tooth, an out of position situation could develop.

Unless the drive has the "zero hour" tolerance band for that axis, it can't recognize that the one little gear tooth slip could jeopardize the entire line. If the drive is monitoring the backlash, it "feels" when the tight coupling between the motor shaft and the gearbox shaft is malfunctioning. The drive's "reflex" is whatever you define: initiate an error message to the machine controller, or perform a safe shutdown, to prevent damage to product or other parts of the machine.

With Rexroth IndraDrive drives and motors for example, your machine's "nervous system" is reflexive and responsive. Predictive maintenance lets you monitor everything -- motor speed, position, acceleration, torque, temperature, current, volt, frequency – that governs the healthy operation of every axis. Based on the parameters you set, intelligence in the drive keeps you fully aware of the "health" of each axis, predicts if that health is degrading, and lets you apply the right "medicine" before the damage grows severe.

Predictive maintenance: It's the ounce of prevention that's worth much more than a pound of cure.

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Images and Graphics:

IndraDrive_H.jpg With today's generation of intelligent servo drives, predictive maintenance capabilities are built directly into the electronics. (Rexroth IndraDrive)

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ADV2578_01.jpg The intelligent drive monitors itself as well as the feedback from the motor it drives – including torque, speed, acceleration and other parameters.


ADV2578_05.jpg With predictive maintenance, the drive detects any variation such as belt slippage that would cause the machine to lose synchronization.


pharmbottles_00128779.jpg Bottle-filling sequences require tight tolerances, which can be monitored, analyzed and flagged by the drive automatically before costly errors occur.