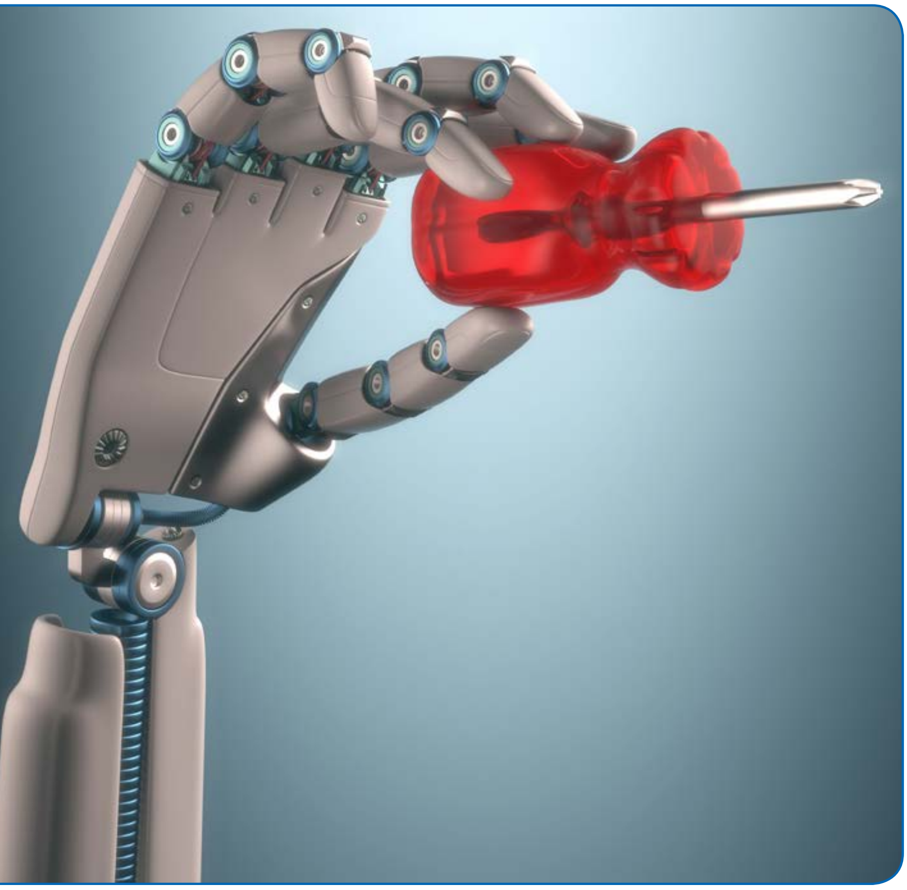
Motors and Mechatronics — Moving to a Higher Plane

Jack McGuinn, Senior Editor

Electric motors (left) from Brother Gearmotors and control systems from Dart Controls are typical of the components found in mechatronic operations. (Photos courtesy Brother Gearmotors and Dart Controls.)

This is an article about motors — preventive motor maintenance, actually. And something else — mechatronics. In today's high-tech manufacturing and industrial use environments, it is near impossible to talk about equally complex motor maintenance and repair-or-replace protocols without it. While it is generally acknowledged that Japanese company Yaskawa first coined — and utilized — mechatronics way back in 1969, what's usually missing is an explanation of why U.S. manufacturing took so long to adopt it. That's a story for another time. But motor-specific mechatronics is the focus here, which has a somewhat briefer history.

"The first International Conference on Advanced Mechatronics (ICAM) was held in Tokyo in 1988, and around that time early insulated gate bipolar transistor (IGBT) technology permitted significant reductions in cost and size of variable frequency drives (VFDs) used with electric motors," explains John Morehead, principal consultant for Motion Mechatronics LLC. "Shortly thereafter more sophisticated vector-controlled drives that modeled the motor's electrical performance inside the controller were introduced. Most methods used to monitor the condition of a motor, such as vibration analysis, required human intervention. Around the beginning of the 21st century as VFD sophistication increased along with microprocessor power some VFD electronic controls were able to use the motor as a transducer for motor condition monitoring."



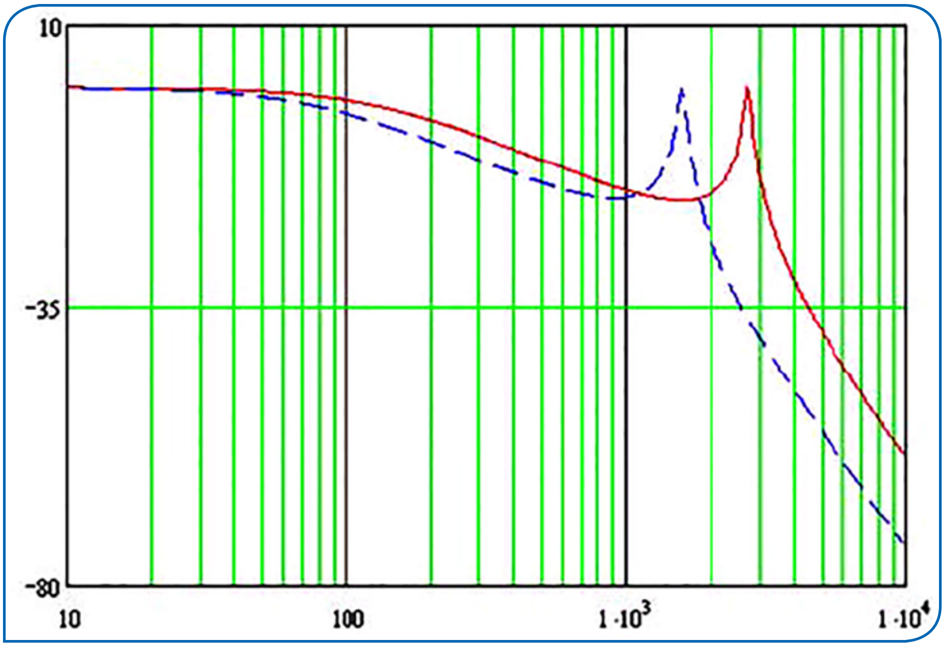
Some, like Kollmorgen manager/training and digital services, Bob White, say the history goes back further. "The discipline of considering the synergy between mechanical, electrical, and control systems has been around since the 50s."

What's more, mechatronics even offers a dash of 1950s Cold War intrigue.

"The adaptation of true mechatronics has a date well before the official release of its name," explains Lee Stephens, Kollmorgen senior systems engineer. "A book on statistical dynamics of control systems (*Introduction to the Statistical Dynamics of Automatic Control Systems* — used paperback 1960 edition available on Amazon) was published in 1952 by an author named V.V. (Vladimir Viktorovich) Solodovnikov. This was where an electronic amplifier was fed an error signal and a gimbal-mounted radar was used to track missiles. The papers were smuggled out of the old Soviet Union and were pretty advanced at that time. Interesting that this was done well before the feared Star Wars program of the U.S. in the 1980s."

How is mechatronics defined? It's a question that elicits both brief and detailed responses.

"We define mechatronics as the union of mechanical, electrical/electronic and software



Screen capture of a Bode plot — used to analyze system mechanics and control electronics (courtesy Kollmorgen).

engineering, resulting in gearmotors utilized with electronic controls and software to perform work more precisely, quickly and reliably than if it were performed using separate, discrete functions," says Juan Avalos, applications engineer for Brother Gearmotors. Adds Mark Lewis, VP marketing & sales, Dart Controls — "The integration of the most applicable facets of mechanical, electrical and computer engineering into a product or process solution, resulting in a better solution than any one of the separate disciplines can deliver."

Kollmorgen's Stephens says that "Mechatronics to me is a melding of the physical expectations of a motion system whether mechanical, electronic, hydraulic, and pneumatic or any hybrid of technologies used to accomplish a physical task. Often, these systems are trying to duplicate, simplify or assist a human function, most often a repetitive motion that a machine can do better. When combining technologies as mentioned earlier, it usually takes a team of engineers as opposed to an individual."

And here's the succinct version, provided by Holling: "The interaction and/or combination of mechanical systems with electronics and electronic motion systems."

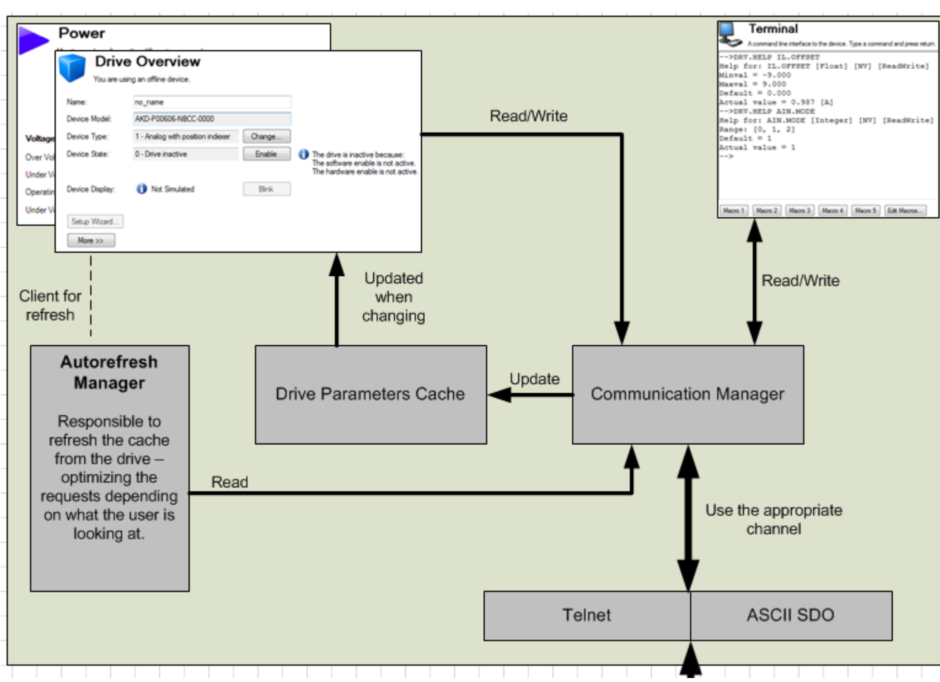
When implemented, how does mechatronics monitor motor maintenance, service life and repair-or-replace issues?

"Mechatronics generally applies more to the total system view and design, which may include service life, repair and replacement," says Holling. "Maintenance is not always addressed, although many modern controls now keep track of operating hours and issue maintenance reminders. Advanced diagnostics that can identify pending failures are the new forefront."

"(The intent of mechatronics) is to remove 'trial and error' from the process of development," explains Dan Wolke, Kollmorgen senior systems engineer. "One by-product is a complete mathematical understanding of the properties of the machine. That "understanding" would allow a much more accurate preventive maintenance schedule, i.e. — a math model that can run independently of the machine to estimate component life.

"System modeling, vibration analysis, and other analytical methods, utilizing state-of-the-art feedback sensors can collect, analyze, and predict preventative maintenance schedules. As a simple example, data collected over time on certain running currents can detect if the mechanical system is wearing excessively if the running current is trending upward above a target range," White adds.

Lewis points out that these same sensors are relied upon to "detect (motor) vibration, current draw, temperature and speed," and that "these data can be collected and transmitted via an IIoT network for analysis and preventative main-



An AKD interaction flow tracks system operation and its various elements (courtesy Kollmorgen).

tenance scheduling."

Brother's Avalos says — "(Regarding) motors, mechatronics has the possibility to project a possible motor defect or fault by monitoring current or running time. It will help enable the user to more optimally time maintenance."

One might wonder if any growing pains exist in implementing a mechatronic motor maintenance system. It depends on where you are starting from.

"As always, it is best when a system is designed for its intended use," advises Holling. "Adding electronic control and motion control to an existing system can improve its performance, but you may not always be able to compensate for a poor existing mechanical design."

And, Avalos adds, "The user needs knowledge of control. A mechanical part is not so difficult to replace, but for controlling the mechanical part, need turning/control knowledge" is needed.

Kollmorgen's White further explains that "Mechatronics is combining a variety of disciplines in designing or retrofitting a particular machine design. Any growing pains would be learning how to consider how each element of the design fits together to optimize the machine performance." Colleague Wolke cautions that "Mechanical design changes needed to achieve additional performance can sometimes be very painful to deal with after metal has already been cut."

"Most engineers graduate with a degree in either mechanical or electrical engineering," Kollmorgen's Ritchie points out. "Educational institutes teach the mechanical and control systems separately from each other, instead of a combined disciplines. The separate disciplines naturally combine in the 'real world' outside of the educational environment."

On the OEM side of things, mechatronics — and the data it provides — are an increasingly larger part of the manufacturing equation. Indeed — it is seemingly all about capturing the info.

"From a drive perspective," says Lewis, "there is a growing interest in the amount of information available from the drive relative to the motor under control; specifically — amp draw, ambient temperature, verification of motor rotation. The OEMs seem to be implementing mechatronics themselves, but need information from products like motor drives to implement their mechatronic solutions."

Avalos points out that "Mechatronics is required for the smart factory technology such as IIoT or Industry 4.0, and as a result the demand will be higher."

"Over the past 20 years," Morehead adds, "industrial and commercial equipment OEMs have widely adopted brushless motors with integral gearing, as well as integral motion controls and their supporting software as an all-in-one mechatronics solution that not only simplifies machine construction but also increases reliability and durability."

Kollmorgen's White adds that "I don't think it's a case of 'implement mechatronic practices' but understanding and implementing tools based on mechatronics. For large opportunities, we have been known to give Control Engineering math model support to customers to help in successful machine design. Most companies that supply motion control systems have been applying these principles as common practice. OEMs who desire to mix motion elements from multiple suppliers tend to have the mechatronic skills to successfully integrate."

"Integrate" is the key word here; mechatronics done right is key to intelligent manufacturing processes. The result? Peak performance up and down the line.

"(For motors), mechatronics will help to output 100% of the motor's ability to make OEM's application-to-output 100% of the application ability. This will affect size down, cost down and improvement of energy efficiency," says Brother's Avalos. To which Morehead adds: "Mechatronics' appeal to manufacturers follows two tracks: systems and economics. Mechatronic systems are more efficient, flexible, reliable and offer scalability compared to individual components. Properly designed mechatronic systems can also be more economic from an installation standpoint and their increased reliability offers not only greater machine lifetimes but also reduces potential for lost revenue as a result of machine downtime."

Given that mechatronics in some form has been around for decades, you have to wonder what comes next — is continuous improvement a given? What would the next iteration look like?

"Advance of AI technology and miniaturization of the electrical parts and cost down of these will help for the future development," says Avalos. "We're only starting to see communications in the form of Internet connectivity or real-time SMS alerts being incorporated into PLCs and other devices," Morehead states. "Fortunately for the industrial world, many

Dart brushless controls are used for system modeling and other analytics. (Courtesy Dart Controls)

developments in this field and other sensing areas are being driven by the smart phone industry; it's economic and size constraints will bring forth new tools that can be incorporated into motors, gearing and controls that would have been unimaginable a decade ago."

Rocky Mountain's Holling believes "(Mechatronics) is still an evolving process, and designers and managers are still learning to understand the global holistic view that mechatronics encompasses, and where mechanics and electronics are combined in an optimal way to deliver the highest performance in a most cost-effective way.

And for White? "Mechatronics as a discipline is becoming more prevalent at a variety of universities as discipline within engineering departments. Many technical and trade schools have embraced Mechatronics. Additional advances will come as increased computational power and sophisticated feedback sensors combine to adapt to a variety of machine conditions. Eventual connectivity to IoT will allow a machine operator to receive maintenance warnings via a smart phone and web connectivity to diagnose machine problems from remote locations.

"It is still an evolving process and designers and managers are still learning to understand the global holistic view that mechatronics encompasses: where mechanics and electronics are combined in an optimal way to deliver the highest performance in a most cost effective way." **PTE**

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IN CLOSING…

We asked the group for some closing comments relative to mechatronics and motor performance, maintenance and repair/replace.

Mark Lewis, Dart Controls

From a drive/control perspective, the IIoT concept is driving suppliers to sense and measure variables in the processes under control. Not sure where mechatronics and IIoT meet, but I believe they do. The key for both are a) solutions that deliver meaningful value-performance, savings and reliability, and b) make use where possible of existing installed base. New technology is cool, USEFUL new technology is really cool.

John Morehead, Motion Mechatronics LLC

In response to the increased deployment of motors in mechatronics systems, over the past decade post-secondary education organizations have begun to offer certifications in the expanded field of mechatronics maintenance. Their curriculum typically includes the primary branches of mechatronics: servo-controls and control theory, mechanical drives, information technology, and electronics.

Dan Wolke and Gordon Ritchie, Kollmorgen

Wolke

To me, Mechatronics is a tool used in the design of a machine or system for a target performance and life. When done properly, it results in a mathematical model of the system that can be used, not only for optimizing performance, but modeling component run life.

But the mechatronic process consumes a huge amount of engineering resources so there becomes a question of how much effort is needed? Example: When NASA designed a rocket, the cost of failure is too great so they spend a large effort into using mechatronic in their design. On the other hand, adding a simple actuator to an existing machine may only require using good known Mechatronic guidelines and not a full Engineering effort to model the performance.

Ritchie

Machine design, going forward, will develop a natural process of marrying mechanical components to control components. By doing so, machine design can take advantage of stiffer mechanical systems and higher resolution feedback. Machines will become more accurate, faster, and more reliable. **PTE**