MECHATRONICS: Gaining Control and Applications

"New" Technology Turning Heads — and Profits.

Jack McGuinn, Senior Editor

Not to bury the lead, but did you know that mechatronics has been around since the 1960s? For some, that is old news. For the majority others — who knew?

Mechatronics sounds like one of those slacker words, e.g. — "agreeance" or "sexting." In reality mechatronics is an engineering-intensive interdisciplinary field that is a critical part of the yet-evolving, revolutionary advances in U.S. manufacturing technology. For today's engineers with the sharpest pencils — especially in the United States — "manufacturing technology" is a bit of an oxymoron. After all, why has it taken *decades* for U.S. manufacturing to embrace mechatronics — something Europe and parts of Asia did years ago? The answer — if one exists to that question — can wait for another time. But one wonders; if there is an explanation, is it perhaps for the same reason that post-WWII U.S. automakers ignored the then-revolutionary, American-devised-provided quality processes that Japan's automakers eagerly adopted to help rebuild devastated country, restore its economy, and revolutionize the automobile industry?

Putting all that aside, mechatronics has arrived and is garnering widespread acceptance here in the U.S. Just one of a number of mechatronics drivers is robotics. According to a recent report from the Robotics Industry Association (RIA), North American orders and shipments of robotics again broke all-time records in 2016; shipments increased 10 percent by volume over 2015, totaling sales of $1.8B.

But *how* is mechatronics defined? *Many* ways, as it turns out, including:

- The science of intelligent machines

Or,

- A multidisciplinary field of science that includes a combination of mechanical engineering, electronics, computer engineering, telecommunications engineering, systems engineering and control engineering

And,

- The incorporation of electronics into mechanisms
- The integration of mechanical engineering with electronics and intelligent computer control
- The use of a synergistic integration of mechanics, electronics, and computer technology to produce enhanced products or systems
- The application of complex decision making to the operation of physical systems
- The addition of intelligence to a mechanical design or replacing mechanical designs with an intelligent electronic solution
- The synergistic combination of mechanical engineering, electronic engineering, and software engineering

And my favorite, from Kevin Hull, application and deployment supervisor / motion control, Yaskawa America Incorporated: "Mechatronics is a way of doing things."

Yaskawa has been "doing things" the mechatronics way since 1969, when Tetsuro Mori, an engineer for Yaskawa Electric Corporation, coined the word.

Existing applications for mechatronics include:

- Machine vision
- Automation and robotics
- Servo-mechanics
- Sensing and control systems
- Automotive engineering, automotive equipment in the design of subsystems such as anti-lock braking systems
- Computer-machine controls, such as computer driven machines like IE CNC milling machines
- Expert systems
- Industrial goods
- Consumer products
- Mechatronics systems
- Medical mechatronics, medical imaging systems
- Structural dynamic systems
- Transportation and vehicular systems
- Mechatronics as the new language of the automobile
- Computer aided and integrated manufacturing systems
- Computer-aided design
- Engineering and manufacturing systems
- Packaging
- Microcontrollers / PLCs
- Mobile apps
- M&E Engineering

But just what, exactly, do mechatronics engineers do?

Many things. According to one online source: "They unite the principles of mechanics, electronics, and computing to generate a simpler, more economical and reliable system. But over the years mechatronics has come to mean a methodology for designing products that exhibit fast, precise performance. These characteristics can be achieved by considering not only the mechanical design, but also the use of servo controls, sensors, and electronics."

There are many engineers who posit that mechatronics is the spawn of robotics. Earlier- generation robotic arms, then unable to coordinate their movements without sensory feedback, have significantly improved thanks to advances in kinematics, dynamics, controls, sensor technology, and high-level programming — i.e., *mechatronics*. A short history:

- During the 1970s, mechatronics was concerned with servo technology used in products such as automatic door openers, vending machines, and autofocus cameras.

- In the 1980s, as information technology was introduced, engineers began to embed microprocessors in mechanical systems to improve their performance.
- The 1990s saw the full arrival of the mechatronic age because of the increased use of computational intelligence in mechatronic products and systems.

Mechatronics is indeed an interdisciplinary field. An effective mechatronics engineer will have a background in mechanical engineering; materials science; electrical engineering; computer engineering (software & hardware engineering); computer science; systems and control engineering; and optical engineering.

With that knowledge mechatronics engineers are tasked with uniting the principles of mechanics, electronics, and computing to generate a simpler, more economical and reliable system. And that system today typically includes modern production equipment consisting of mechatronic modules that are integrated according to a "control architecture;" the most used architectures involve hierarchy, polyarchy, heterarchy (nobody said this was easy), and hybrid. The methods for achieving a technical effect are described by control algorithms, which might or might not utilize formal methods in their design.

So why now mechatronics? Was there a tipping point regarding the field's now pervasive influence in manufacturing?

"A stronger and more refined integration between hardware and software has certainly been a governing factor," says Yaskawa's Hull. "Solutions have become easier to apply and maintain in production environments. Applications that may have demanded too much computing power in the past to be feasible are now more common and require significantly less support from a short list of experts."

And since his company invented this process, it only makes sense to ask how Yaskawa defines it, in addition to "way of doing things." "It is," says Hull, "a philosophy made possible by the number of refined technologies that can be easily incorporated with one another like never before. For example, if a conveyor line goes down, there may be a faulty variable frequency drive (VFD) which provides power to the conveyors motor. A mechatronics philosophy means the VFD probably has a web server available. A local technician may be able to ask for remote assistance in troubleshooting the problem, allowing an engineer to remotely connect to the drive and view the faults codes. Once a new drive is installed, a smart phone app might be used to upload parameters from the old drive and copy them into the replacement unit. The time to troubleshoot the problem and implement a solution can be greatly reduced."

We put the same question to Cindy Daneker, Sr. Applications Engineer for SKF Linear & Actuation Technology (which, as a Swedish company, has been implementing mechatronics systems for around 50 years).

"Many customers have been using hydraulic and pneumatics for many years, but due to the maintenance required, and environmental concerns, they are switching to electromechanical solutions now. In the long run the electromechanical solutions are more cost effective. Accuracy and repeatability are also improved with the use of mechatronics, and industry today, with its advancements, requires this."

Yaskawa 3-axis gantry system utilizing G-Code programming within MotionWorks IEC software to perform coordinated motion control (Photos courtesy Yaskawa).

After poring through a litany of definitions for mechatronics engineer, one might wonder if it is just a dressed-up name for what used to be known as "system integrators?"

"Sure," says Hull. "Mechatronics is the integration of several disciplines. A system integrator has always played the role of pairing mechanical devices to their electronic controls, interfacing various pieces of equipment together, and determining attainable cycle rates when all the components are considered as a unit."

And at SKF, says Daneker, "We often sell to system integrators, OEMs and end users (through distribution). The mechatronics engineers in our group range from application engineers helping size and select products, to actual design engineers at the factory levels."

Returning to robotics and its influence on the growth of mechatronics, Daneker believes "Robotics is just one application driving mechatronics, but also medical, oil & gas and ergonomics to name a few."

Hull concurs, adding, "While I don't think robotics has been a key driver, a robot exemplifies one of the greatest mechatronics solutions created. Physics, mechanics, electronics, software, pneumatics, vision, and even tactile feedback all come together as a single unit to provide increasingly unique and innovative automation."

It would seem that companies marketing mechatronics systems would be required to have all the elements — from mechanical to electrical to software and more — under one technological, extremely vertical engineering umbrella.

Supporting that notion regarding engineering disciplines is Bill Leang, manager, motion engineering, Yaskawa America, Inc.

"In order to provide a complete mechatronics system, a company needs to have electrical/electronics engineers, software engineers, and mechanical engineers. These engineers work together in the design, fabrication, and test of the system. Taking a system approach is very important." Leang explains that the "system components can be sourced from outside vendors."

How much can all this cost, you may ask? Unfortunately, we can't tell you.

"There's no way to put a price on mechatronics," says Hull. (In my world, that usually means get ready to dig deep.) "It's a design philosophy more than anything. It could be argued that a great mechatronics design will save money in the long run."

Daneker explains that at SKF, "Oftentimes, we sell components that may cost anywhere from a few dollars (linear ball bearings) to over $100K (roller screws). There are times we also offer sub-assemblies which will also vary by price. In general, for a product such as a roller screw, the initial cost will be higher than a hydraulic cylinder, but the overall cost of ownership will be less expensive in the long run.

Given that mechatronics engineers apparently need to be virtual polymaths, what educational background do mechatronics engineers generally possess? "

Hull says that "Mechatronics engineers typically have a degree in mechanical, electrical, or computer engineering, but it takes more than just a degree to be a great mechatronics engineer. Engineers who like working with their hands, like to build things, and belong to school-sponsored clubs such as first robotics or building electric vehicles are great candidates. On-the- job training can't be ignored either; having an open mind and a desire to learn more about the interdependencies between the mechatronics disciplines really goes a long way."

Daneker adds that "Most (SKF) mechatronics engineers have degrees in mechanical or electrical engineering. Of course, there is a learning curve to learn about the individual products and applications where they can be used."

Given the ongoing shortage of skilled workers — at all levels — how difficult has it been to recruit and keep mechatronics engineers? At SKF, says Daneker, somewhat surprisingly, "Since mechatronics touches a wide array of industries, keeping mechatronics engineers is not an issue, especially since this industry is growing."

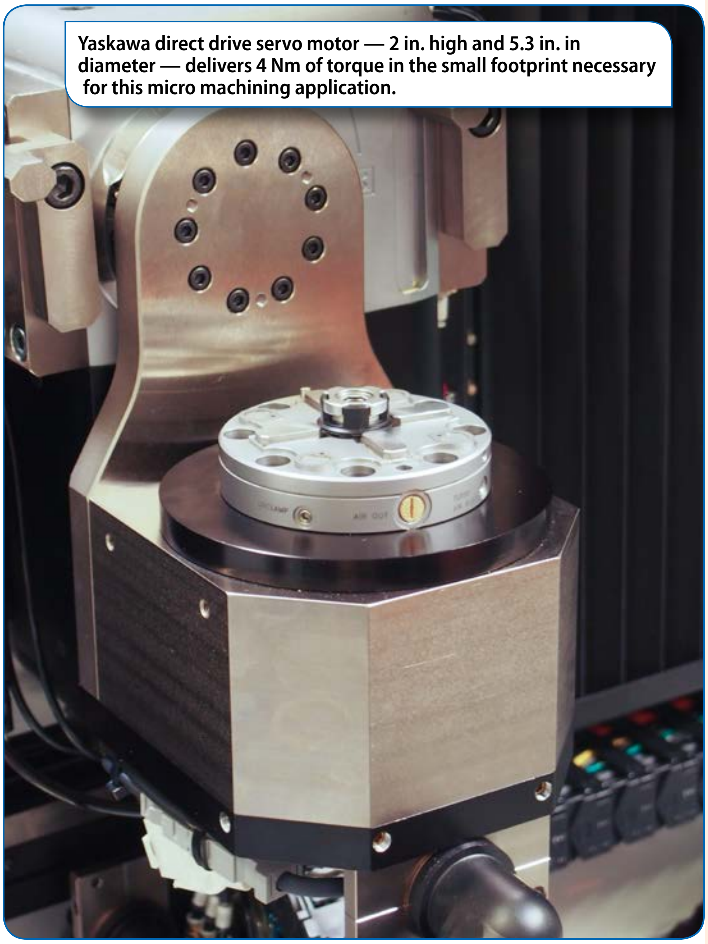
While at Yaskawa, even with its mechatronics DNA, Hull says "It's an ongoing challenge to find the right people with the passion required to be a great mechatronics engineer. Engineering can be complicated, challenging and frustrating at times, but the reward of seeing months or years of hard work come together is worth it. There's a real sense of accomplishment in solving engineering problems that improve on prior design using the latest innovations in mechatronics."

OK. Here's a scenario: one of a manufacturer's conveyor lines suddenly goes down — how does mechatronics save the day?

"(Mechatronics) is a philosophy made possible by the number of refined technologies that can be easily incorporated with one another like never before," Hull explains. "For example, if a conveyor line goes down, there may be a faulty variable frequency drive (VFD) which provides power to the conveyors motor. A mechatronics philosophy means the VFD probably has a web server available. A local technician may be able to ask for remote assistance in troubleshooting the problem, allowing an engineer to remotely connect to the drive and view the faults codes. Once a new drive is installed, a smart phone app might be used to upload parameters from the old drive and copy them into the replacement unit. The time to troubleshoot the problem and implement a solution can be greatly reduced."

The above provides a smooth segue for asking, how does mechatronics improve overall quality?

"Reliability, accuracy and repeatability are key with me-



Yaskawa direct drive servo motor — 2 in. high and 5.3 in. in diameter — delivers 4 Nm of torque in the small footprint necessary for this micro machining application.

chatronics over products such as hydraulics and pneumatics," says Daneker.

It is Hull's belief that "Mechatronics improves quality because machines designed as a homogeneous unit are better at things like holding tolerances, identifying material defects and eliminating them before insertion into the final product, and taking measurements or visually confirming each and every part made.

Preventive maintenance is another area in which mechatronics creates a good deal of conversation — and for good reason.

"(Preventive maintenance) plays a huge role," Hull asserts. "Again, because of tighter integration of high-precision sensors with fast CPUs and data acquisition techniques, performance characteristics of equipment can be easily benchmarked. Machines can re-check the performance of their mechanical components at regular intervals and compare the latest performance data to the factory benchmark conditions. If performance metrics indicate significant differences, users can be alerted to schedule investigative maintenance rather than waiting for a complete breakdown to occur.

And how, if at all, do the above translate to mechatronics-driven energy savings and effectiveness?

Hull frankly states that "Mechatronics (does not inherently) improve energy usage." The good news, he goes on to say, is that "Companies and designers with a mechatronic philosophy ("a way of doing things" — remember?) will likely employ design elements which provide energy-efficient solutions. Providing energy efficiency might previously have been thought of as an extra effort; but a tightly integrated system using various sensors, electronics and data can be more easily optimized by slowing conveyors during lighter production runs, or push energy back to the power company instead of wasting it through mechanical brakes or regenerative resistors."

What is next for mechatronics? After 50-odd years — glass half-full or half-empty?

"The glass is half-full," says Daneker. "Due to the accuracy, reliability, repeatability and cost of ownership for mechatronics compared to other solutions, this industry is continuing to grow."

And Hull?

"I'm optimistic about the future of mechatronics. Automation will continue to provide a greater degree of flexibility in ways we can only begin to imagine. Companion ideologies such as "Internet of Things" (IoT) are coming into play. The inclusion of real-time business information into automation processes will lead to new products and uniquely customized product choices that would have never been possible before." **PTE**

(Primary sources for this article: *typesofengineeringdegrees.org; engr.ncsu.edu* (U. South Carolina; *journals.elsevier.com*; *ocw.mit.edu* (MIT U.); *engineersaustralia.org*; wikipedia.org; *sciencedirect.com;gla.ac.uk* (U. Glasgow); *technosoft-inv.com*; *tryengineering.org*.)

WE'VE BEEN TEACHING THIS STUFF FOR YEARS

Following is a brief first-person explanation of mechatronics from the academia side, provided by David L. Trumper, Professor of Mechanical Engineering at Massachusetts Institute of Technology (MIT). His class has an enrollment limit of 24 students due to lab size, and routinely fills this limit. Graduate students are the primary customers, who view it as highly valuable for supporting their research in many fields, since they learn a great deal about instrumentation and control.

I started teaching at MIT in 1993. But before that, Prof. Will Durfee taught a course at MIT called Smart Machines, which was also a mechatronics course. He had been teaching that for maybe five years before I started. As well, Prof. Kevin Craig, who was at RPI (Rensselaer Polytechnic Institute) back then, had been teaching mechatronics for some time; it would be worthwhile to follow up on Prof. Craig's work in this area.

If one looks realistically, there were lots of courses at universities that taught aspects of mechatronics for a long time, although they might not have been called that. For instance, Prof. Tomizuka at Berkeley was associated with hard disk technology from a controls perspective. Prof. T.C. Tsao, then at University of Illinois, Champaign-Urbana (now at UCLA) also taught that kind of material.

Oversees, the Dutch universities had lots of mechatronics education, primarily due to the influence of Philips company, which pioneered optical drives, such as CD players. Dr. Jan van Eijk at Philips, and later University of Delft, was a real pioneer in this area. And the Japanese universities and industry were working in this area as well.

In summary, I don't think mechatronics is in any way a new field, as it has roots in many areas of electromechanics, controls, electronics, software, etc. These days, the pervasive availability of low-cost computation is driving mechatronic solutions into many more devices. Also, students are easily able to access the tools needed to implement mechatronic solutions.

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