The Case for Hollow-Shaft Torque Motors

PERMANENT-MAGNET, SYNCHRONOUS-TORQUE MOTORS OFFER SIGNIFICANT ADVANTAGES ON HIGH-ENERGY-CONSUMING AND HIGH-DYNAMIC APPLICATIONS.

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Hollow-shaft torque motors are used in a wide variety of machinery.

Today's machine designer must evaluate more factors than ever in approaching a new project. Likewise, the integrator and retrofit engineer have expanded options—not only as a result of new technologies but also because of critical areas of focus such as reduced energy consumption, faster assembly time, vendor consolidation and smaller footprint achievement.

In the realm of motion control, one type of motor with a relatively short history has made significant advancements that necessitate a new look at its potential in many application areas. These applications range from machine tool rotary tables to various packaging, printing, converting, extruding, papermaking, plastic film and materials handling machinery—i.e., anywhere direction must be reversed with a very high degree of accuracy, zero backlash (hysteresis) and the maintaining of motion control—contrasting the necessary decoupling of a conventional motor and gearbox.

Enter the often-overlooked permanent-magnet, synchronous-torque motor.

Hollow-shaft torque motors offer various design integration options coupled with advanced performance features for greater energy-efficiency, substantial component reduction and significantly smaller footprints in today's machine drivetrains.

Torque motors are direct drives built for rotary axes where high torque and high precision are required at relatively low speeds. With their significantly lower installation time, maintenance requirements, component part count and space allowance, these motor types are frequently viable alternatives to geared motors.

Two popular varieties of torque motors exist today:

Complete-torque motor—requiring only direct flange mounting to the machine and connection of the rotor to the machine shaft

• Built-in-torque motor—the stator and rotor are supplied as individual components that are directly integrated into the machine mechanics

• Complete-torque motors are often found on extruder main drives, feed heads on injection molding machines, roller drives on papermaking machines, wire drawing devices, textile machine web stretching and winders/cross cutters on packaging equipment.

Built-in-torque motors are typically used on machine tool rotary tables, swivel axes, dynamic tool turrets and turning spindles as well as printing press cylinders, chill rolls in cast film and foil stretching machines, indexing tables in metal-forming presses and all other types of high-dynamic, high-precision path and speed control applications.

A similarity is that both types of torque motors feature a hollow shaft, thus allowing media and/or mechanical components to be guided through the rotor cavity.

Torque motors are multiple-pair-pole-synchronous motors, similar in operation to rotary-synchronous-servo motors. The rotor is equipped with permanent magnets, while the stator contains the motor windings. The high number of pole pairs leads to a design generating high maximum torque at low speeds. In the past, since eddy current losses increase with the number of pole pairs and the running speed of the motor, torque motors were considered applicable only at relatively low speeds. But new water-cooled designs have countered this principle, allowing a high power density. Today's torque motors can accommodate speeds of 1,000 rpm or higher.

As a result of these higher-pole-pair designs—and because many mechanical power transmission components that generate backlash, heat, friction and noise are eliminated—torque motors offer these benefits to designers:

- small footprint = high torque density
- excellent rotational accuracy and repeatability = direct load control
- space-saving machine designs = elimination of gear units and belt transmissions
- low maintenance = fewer mechanical parts in the drivetrain
- high energy efficiency = mechanical losses in the drivetrain are eliminated

While higher in cost than geared motors, it is currently estimated that torque motors offer the designer a payback of three to four years in energy

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savings alone, which does not include the immediate, increased performance and upfront cost savings—both in installation and maintenance. Obvious vendor reduction and inventory advantages are also realized through the use of these motors.

On a typical multi-layer blown-film line, for example, the use of torque motors can reduce the footprint of the extrusion section by half, and the consumed production space decreases accordingly, leading to an increase in production rates per square foot.

Torque motors were also long-thought to be susceptible to chemical and other ambient atmospheric contamination, but new designs have been adapted to withstand corrosive atmospheres such as a paper mill dry hood, for example; and, being water-cooled, they are performing satisfactorily in many harsh environments without heat damage. Enclosures are available up to an IP54 rating, with overload capability

Typical applications for today's advanced torque motors include (from top) converting equipment, printing presses and machine tool rotary tables.

up to 2.5 times the rated torque.

Torque motors reduce mechanical efficiency losses to an absolute minimum because they eliminate mechanical transmission in the drivetrain. Compared to geared motor solutions, the efficiency gain is typically in the range of 10 percent, while the gain is closer to 70 percent when hydraulic motors are replaced in applications such as injection molding machines. Further, due to the direct and constant control of the load shaft on torque motors—with no backlash or decoupling occurring—a significantly higher precision in motion is achieved. This is not possible in a geared or belt-driven solution.

For example, in the production of stretched film, torque motors used with chill rolls, pull rolls, stretch rolls and winders have resulted in dramatic improvement in production quality. Because the likelihood of cracks in the web is minimized, a more accurate speed control of the direct-driven rolls results in faster start-ups during the changeover from one film product to another. In addition, the higher control accuracy enables the production of a thinner film that is 10 times more consistent in its thickness. Likewise, the stiff drivetrain configuration achieved with torque motors allows faster ramping up and down in cyclic applications, leading to shorter cycles and increased product output in the same time period. In many applications with very short cyclic times—such as indexing tables or injection molding machines—the changeover from conventional drives to direct-driven solutions has resulted in production increases of 25–30 percent, typically. These results indicate that a lower component count now means a lower product lifecycle cost as well as reduced potential failure rates in the field.

Other features on today's torque motors that make them more appealing for the machine designer include:

- absolute value or incremental encoders, or resolvers for enhanced motion control
- electronic nameplate for faster commissioning
- horizontal or vertical mounting options
- bearing options for axial-thrust applications
- PTC resistors in each phase, in addition to standard KTY thermistors for optimum temp monitoring

Mechatronics is also critical for direct drives such as torque and linear motors in the integration process because the electronic machine control protocols are so crucial in monitoring and executing the electromechanical motions. A keen knowledge of mechanical, electrical and electronic engineering is fundamental in determining the proper unit to suit the load. Mechatronics addresses such topics for the machine builder as proper encoder location, reaction versus dynamic force calculations and how best to integrate a high-dynamic direct drive mechanically into the machine.

Additionally, through various advanced computerized simulation techniques, mechatronic performance can be validated, and troubleshooting on the design can be accomplished before the first machine is ever built. Even in the field, before and after a retrofit or rebuild, the mechatronic services currently available can be used for product application determination, full performance analysis and controls compatibility. While the performance of a new motor or drive might be deemed satisfactory by mechatronic analysis, other mechanical, electrical or electronic components might be found lacking. It is precisely this comprehensive, integrated approach that is fast-earning mechatronics its place in the overall scheme of machine development and utilization.

In conclusion, with today's emphasis on cost containment, energy efficiency and higher productivity on every type of machine design, it is imperative that all viable options be explored. In designing the drivetrain on many machines, the advantages of torque motors described in this paper will have a positive impact on the overall project results. Torque motors can offer great flexibility in design, retrofit and rebuild applications, and they have expanded capabilities that justify their implementation on more types of machines.

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