Advertise | Subscribe

Home | FMA | TPA | FABTECH | Nuts & Bolts Foundation | The Fabricator Blog | Article Archive | Supplier Search | Video Vault | Site Map

EXCLUSIVE TO THEFABRICATOR.COM

Newer linear-drive technology improves waterjet accuracy, reduces costs

By Dr. John H. Olsen, Contributing Writer
December 15, 2009

Recent developments in linear-drive technology are designed to improve waterjet cutting accuracy and safety, while making high-precision machines more affordable. Find out more about this traction-drive system that has its roots in railroad locomotives.

If an image is not displayed, click the hyperlinked figure number to view it.

Traction-drive System on an Abrasive Waterjet Cutting Table

Previous articles I've written about waterjet cutting have covered the extremely wide range of parts modern abrasive waterjet cutting systems can produce. They also have explained how part accuracy has been dramatically improved by a better understanding of how the jet stream of an abrasive waterjet bends during cutting and by improved machine control software that takes advantage of this knowledge. However, the parts produced by an abrasive waterjet cutting machine are only as accurate as the electromechanical system that moves the cutting nozzle in the X, Y, and Z axes.

Abrasive waterjet designers have always faced a compromise in using traditional machine tool motion control systems because none of them are perfectly matched to the unique requirements of waterjet technology. A recent patent application has introduced a precise *traction-drive* linear-motion system that appears to be ideal for abrasive waterjet applications and promises a higher level of accuracy.

The "Ideal" Motion System

The ideal linear-motion device for an abrasive waterjet cutting system should provide the following:

1. Smooth,vibration-free linear motion over a wide range of speeds, from rapid traverse speed to the very low speeds needed for cutting thick or hard material.
2. Precise control of linear position, speed, acceleration, and rate of change of acceleration.
3. Long-term, reliable operation in a wet, abrasive-laden environment without requiring expensive sealed bellows or other costly protection systems.
4. Lubricant-free contact surfaces to avoid attracting contaminants.
5. Applicability to a large range of lengths in order to be usable in many cutting table sizes desired by the marketplace.
6. Relatively low forces in keeping with the very modest forces required to move a waterjet nozzle and the desire for maximum system safety.
7. Low overall cost, particularly for larger cutting tables.

Traditional Motion Systems

Traditional servomotor-driven, precision-ground ball screw systems are the *de facto* standard for high-precision abrasive waterjet cutting systems, but they are costly, particularly in the longer lengths required for large cutting tables. They also have serious vibration issues in long applications and at high speeds. Their precision-machined, lubricated contact surfaces mean that they are extremely sensitive to abrasive and water contamination. This further adds to their expense by requiring sealed bellows or other protection systems.

Because these servo-driven ball screw systems deliver the strong cutting forces required by a traditional mechanical cutting tool, they are vastly overmatched to the relatively light forces a waterjet cutting nozzle requires.

All of these factors combine to make a system that is more costly than it really needs to be.

Rack-and-pinion systems and various belt-drive systems are more tolerant of contaminants and can be less expensive than precision ball screws. They generally do not require the sophisticated contamination protection ball screws need. They also can be adapted to many sizes. Unfortunately, like ball screws, these systems typically generate much greater nozzle-motion forces than really are required, resulting in extra expense and basic safety concerns. However, the key drawback of these systems is that they are simply not capable of the precision motion required by modern precision abrasive waterjet cutting systems. For this reason, these motion systems generally are found only on low-precision cutting systems.

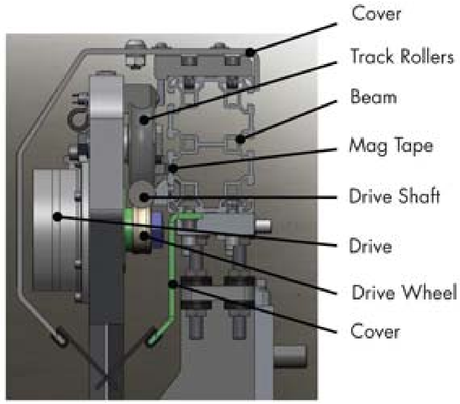

Figure 1
Traction-drive Mechanism

Linear motor-drive systems have some characteristics that are well-suited to abrasive waterjet applications. They are relatively tolerant of dirty operating conditions and contaminants and can provide a smooth motion over a range of speeds. They can be combined with modern magnetic linear encoder systems and appropriate feedback control to create a positioning system with excellent resolution and accuracy.

Linear motor-driven systems suffer from the fact that they lose position in power-off situations, unless a brake is added. Most important, these systems are costly. Because of this they have pretty much disappeared from the abrasive waterjet cutting scene.

Introducing Traction Drive With Linear Encoder Feedback/Feedforward Control

In the traction-drive system, three elements work together to provide a precision motion control system that is well-suited to abrasive waterjet cutting applications.

The first element is the actual traction-drive mechanism (**Figure 1**). This mechanism uses the time-tested, steel-on-steel traction capability found in railroad locomotives. A hardened steel drive wheel mounted to a movable carriage assembly is pressed against a hardened steel rail by a spring flexure mechanism. Rotation of the drive wheel by a brushless synchronous motor causes the carriage to move along the rail.

This drive system is extremely robust and operates well in the worst imaginable wet and abrasive-laden environment,s as demonstrated by the millions of miles railroad locomotives travel in conditions ranging from heavy rain to drifting sand.

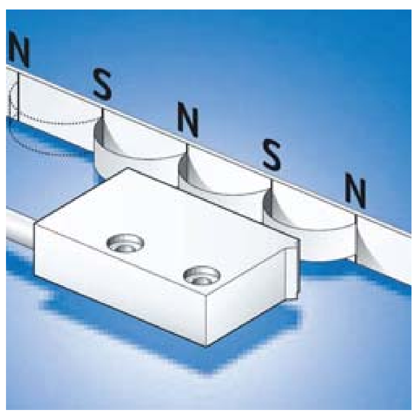

Figure 2
Magnetic Linear Encoder System Used With Traction Drive

The system provides smooth movement over many speeds and accelerations and can be designed to create only the forces actually needed to move the cutting nozzle smoothly, which makes it safer to operate. No lubricants are required for the drive surfaces, which further enhances reliability and minimizes wear in a contaminated environment. The drive is lower in cost than traditional linear-drive systems and can be easily expanded in size by merely lengthening the steel guide rail. It accommodates off-the-shelf extruded rail guides.

The potential drawback of the traction-drive mechanism is that it is what engineers refer to as a "loosely coupled" drive system. There is no continuous positive mechanical linkage between the moving carriage and the rail, as found between a ball screw and ball nut, or a rack and pinion. Thus the need for the second element—a precision magnetic linear encoder system (**Figure 2**).

Not long ago long-length linear encoders were both exotic and costly. This is no longer the case. Now these precision magnetic devices are readily available in virtually limitless lengths at reasonable costs. They are reliable and quite insensitive to contaminants and dirty conditions. Moreover, they are highly accurate and have a resolution down to 1 micron (0.00004 in.), more than adequate for the most precise abrasive waterjet application. Indeed, the inherent accuracy of this system is on par with the accuracy of a linear-motor drive, which also relies on a linear encoder for determining position.

The final element of the traction-drive system is the electronic drive control, shown in block diagram form in **Figure 3**. The traction-drive mechanism provides the motive power to move the carriage smoothly along the rail. The linear encoder provides the data to determine precisely where the carriage is. The drive control links these, along with input from the machine control computer, in a unique feedback/feedforward control loop.

Conceptually, the system functions as follows: The drive control first takes input from the machine control computer ("Data Source" in Figure 3) to determine the desired direction, acceleration, speed, and distance of motion based on the toolpath and precomputed velocity profile associated with the part being made. The drive control then instructs the traction-drive motor to provide the desired carriage acceleration, speed, and distance based on an assumed coupling between the drive wheel and the rail. The drive control monitors the actual carriage motion based on the input from the linear encoder sensor and adjusts its instructions to the traction-drive motor based on what is actually happening. This is the *feedback* part of the control.

In addition, the drive control modifies its intended future commands to the traction drive based on the currently measured drive wheel/rail coupling. This is the *feedforward* part of the control. The end result of this feedback/feedforward control approach is that the mechanically "loosely coupled" drive system becomes a "close-coupled" drive that automatically adjusts for changes in conditions, such as possible contaminants on the rails and long-term wear.

This new drive technology, already available on some machines, improves waterjet cutting accuracy while reducing costs, making the process available for a greater range of manufacturers, large and small.

This article can be found at:
http://www.thefabricator.com/WaterjetCutting/WaterjetCutting_Article.cfm?ID=2366

Contact us at: FMA Communications, Inc. 833 Featherstone Road Rockford, IL 61107 815-399-8700 E-mail: info@thefabricator.com