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Total Stations

The Other Machine Control Sensor and More

For the past decade, most of the emphasis and buzz around machine Control has been about GPS. This is to be expected due to the overall versatility and lack of operational constraints that GPS brings to the table. However, there have been other positioning technologies in use on the construction site for even longer. We old-timers will remember transits, tapes, optical levels and lasers used for grade control and layout. The early machine control systems utilized lasers and sonic tracers. As layout got more demanding and data flow to computer systems became more common place, the optical total station began having a greater presence on construction sites all over the globe. Then in the mid-nineteen nineties, total stations began to appear on job sites as machine control positioning sensors. In this article, I will focus on the total station's role in construction layout and machine control and some of their capabilities may surprise you.

In the past decade, manufacturers have made tremendous strides in developing optical total stations specifically designed for the construction site. In the early 1990's the construction industry was slow to adopt total station technology. Manufacturers attempted to increase the adoption rate by offering lower priced, de-featured versions of the models they traditionally sold to surveyors. As their understanding of the industry's requirements increased; new models were introduced that better fit the contractor's needs for layout, as-built's, volume calculations and machine control applications. These instruments are highly specialized, yet very versatile, serving many purposes on the job site.

The most advanced models in this category are capable of machine control and share common characteristics. They are motorized, robotic total stations capable of one person or unmanned operation. They contain reflectorless Electronic Distance Meter (EDM) technology and may also contain imaging capabilities as well. They can be used for machine control as well as standard surveying tasks and also have the capability to perform surface scans.

When used for machine control applications these specialized instruments differ from standard surveying instruments is several significant ways. The standard surveying total station is designed to measure to static (non-moving) objects. Therefore, a slight time delay in the obtaining the angle and distance components of a measurement have no impact on the measured position. If the prism is held by a steady hand and properly plumbed the resultant position

continued on page 46

Hahn, *continued from page 48*
will be correct. This type of measurement mode is often referred to as "static". However, measurements to moving objects present a completely different set of requirements. These measurements are referred to as being in the "dynamic operations mode". Depending on the vector and velocity of the moving target, positioning errors will occur if the angles and distances are not captured simultaneously. To overcome this inherent error, manufacturers needed to develop total stations wherein the angle and distance information was synchronized or with very low latency. As the target (machine) was moving (dynamic), these instruments needed to have a very fast measurement update rate, so position information could be relayed to the machine in real-time. They must also possess very fast radios to relay the position data to the machines they are controlling or that latency will result in positioning errors as well. When all of these challenges were overcome the resultant instrument was capable of traditional surveying work and use as a machine control sensor. Total stations are capable of higher positioning accuracy than unaided GNSS (GPS) technology, especially in the vertical (elevation) component. This makes them a very good for fine and finish grade applications. Therefore, the first systems developed were made for motor graders and pavers. There are several excellent products in this group, including Trimble's SPS Universal Total Station, Leica's PowerTracker and Topcon's LPS-900. All are fast-tracking robotic total stations with synchronized angle and distance measurements and high update rates.

To give you an idea of how advanced these units are; I will provide some specifications. The angular accuracy of these units is as high as +/- one arc second. Distance measurements are accurate to +/- 1mm in static mode and +/- 5mm in tracking mode. Position update rates are very high at 20 times per second. Combining these capabilities, one manufacturer states they can track machines at up to 35 MPH.

The total stations instruments themselves are not the only advancements that make the systems construction site-applicable. The software on-board these instruments (or contained within their hand-held field controllers) has been specialized as well. The user interface and application software has been tailored to the needs of the job site. These are not the same application programs that are sold into the surveying market. Topcon, Leica and Trimble have all created contactor-friendly, construction application-specific, programs to support the workflows of construction projects. They have names like "Site Foreman", "Layout Manager", "Site Controller" and "Layout Master". Obviously, these were not named or developed with the land surveyor in mind. To improve the user interface; they all utilize color graphics and construction-centric terminology.

So now we have available very productive, accurate and powerful robotic total stations for construction layout, topo verification, as-built's, earthwork quantity determination, with reflectorless and scanning capabilities. And, oh-by-the-way- they are also machine control sensors.

The first total station used for machine control, that I am aware of, was the Spectra Precision (Geodimeter) Advanced Tracking Sensor (ATS). This was developed and introduced to the market in the mid 1990's. The first use was for tracking motor graders, as part of Spectra Precision's Blade Pro 3D system. Soon, third party integrators began including the sensor as part of their solution. I believe the first was Somero Enterprises, who used the ATS for their automated screed system. Since then, many motor grader and paving

solution providers have integrated these advanced sensors. Leica, alone is providing sensors for several paving machine makers, including Gomaco, Miller Formless, Power Curbers and Wirtgen. Somero offers a new version the ATS (the Trimble SPS Universal Total Station) as part of its 3-D Profiler system. Another early use was for the guidance of tunnel boring machines.

Just as GNSS systems do today, these total stations provide real-time positioning information. That position data is compared to design positions and appropriate actions takes place via the machine control system. However, total stations do not require line-of-sight to the satellites. They can replace GNSS technology when machines are working under obstructions or even underground. Manufacturers have made it easy to switch between GPS and total station sensors for added flexibility. Total stations are, of course, constrained by the required line-of-sight between the total station and the target on the machine and their limited range can also become an issue. Some manufacturers have overcome this constraint by making it possible for multiple total stations to be "strung together" to allow for uninterrupted machine control operation over greater distances. Also keep in mind that vertical accuracies are higher with a total station than with un-aided GNSS systems. It is possible to augment or enhance GNSS positions with laser-based instruments but line-of-sight to the sky must be available and surface scanning capability would not be available.

Surface scanning is a common capability with this class of instrument. Once the instrument's position and orientation are established, operators define a scanning area and interval for measurements. Then the instrument automatically (and un-aided) makes the required shots needed to determine the shape and volume of the desired area. Applications include stockpile and borrow pit measurements to determine volumes and quantities. I am sure you can think of many other applications that could benefit while you step away for a cup of coffee, or tend to another job site chore.

These new instruments (and their controlling software) fill many needs on the job site and compliment GNSS technology in a wide range of applications. Some of the newer models even include spatial imaging capabilities. Add to this the many machine control applications and you will conclude that a total station is no longer "just a total station".

To sum up the applications and advantages: The more expensive the material you are laying down is, the more you can save by using technologies with a very accurate vertical component (think paving and fine grading). You can augment GPS with lasers to arrive there, but then line of sight to the satellites is non-negotiable. For an all-round, flexible workhorse, complementing GPS technology, the new generation of machine control-capable total stations is hard to beat.

Your investigation into these units may surprise you as to just how versatile and productive they are. And that can impact your bottom line. MC

Resources:

Leica: www.leica-geosystems.us/en/Machine-Control_4677.htm

Topcon: www.topconpositioning.com/products/machine-control/3d/lps-900

Trimble: www.trimble.com/construction/heavy-and-highway/site-positioning-systems/Universal_Total_Stations.aspx?dtID=overview&

Paul Hahn has more than 30 years of experience, and has held senior management positions at Carl Zeiss, Nikon, Geotronics, Spectra Precision, and Trimble, and is now a consultant.