Triple Redundant Encoders with Self-calibration

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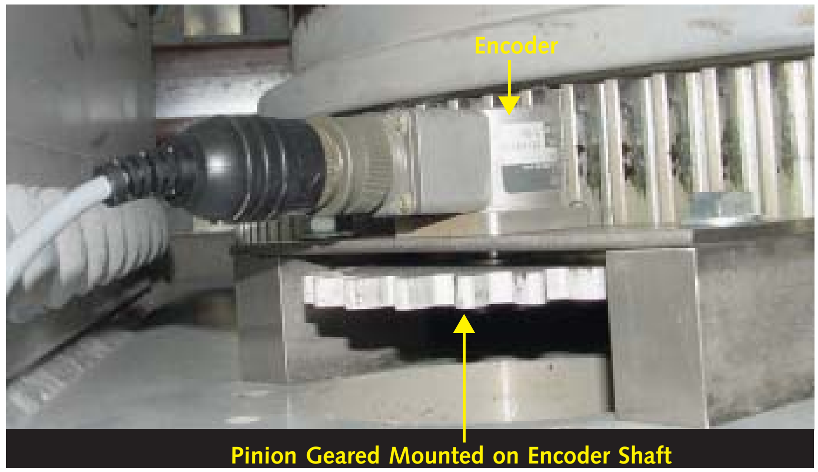

Figure 1: Encoder with pinon geared shaft.

Many industrial positioning applications make use of rotary, incremental encoders with great success. This encoder form provides a pulse train of a fixed number of pulses per revolution to separate count input device, which can be a PLC or PC, or a simple counter.

The encoder output signal can be as simple as a logic high for each count, with no indication of direction of rotation, or it can furnish a separate output that, by being high or low, will indicate direction, or it can be a quadrature output, where two channels, A and B, each issue a pulse train offset from each other by half a wave.

The input device can then determine count direction by the order of the two channel signals: if A high arrives before B high the direction is one way, if B high arrives before A high, it is the other. By reading both channels, as well as reading leading high and low, the quadrature encoder also quadruples the resolution.

But the greatest benefit of the quadrature encoder is its ability to ensure count integrity. The two other types of incremental encoder types have one great flaw: they can pick up false counts from machine vibrations, which may cause an encoder that is otherwise stopped, but right on the edge of a signal, to flutter back and forth over the signal. Since the signal is not directional, it will just keep adding to the count. If the controlled machine makes many stops during a travel between possible homing positions (where the counter can be reset to a known value), it can be detrimental to the operation.

Another potential cause of incorrect count input is the way the encoder shaft is connected to the moving element. There are essentially only two ways this can be done; you can either turn the encoder shaft via a friction wheel (or other forms of friction connection), or you can make a fixed connection, be it rack and pinion (or other form of gearing) or a coupling. Any form of friction connection introduces three areas of potential problems caused by the friction wheel: 1. initial circumference, 2. changes to circumference, and 3. slippage.

While the initial circumference can be controlled to some extent by high manufacturing standards and use of materials, which do not change size to any significant amount due to environmental forces, it is only the beginning. The wheel must also be kept very clean, since dirt buildup will change the wheels circumference, and it must also be protected from wear, which can be induced by even a slight misalignment between wheel and surface. And finally there is slippage, which can stem from any form of contamination of the friction surface, such as water, lubricants, dust, etc..

As long as the travel between fixed reset or homing points is fairly small in relation to the potential miscounts, it will generally not impede the performance of the system to any meaningful degree, but even the smallest error can become significant if multiplied enough times through long travels between reset points.

With all these negatives arrayed against the friction wheel, it should be an easy choice to select the geared or coupled connection. If life was just that easy. Sometimes you must measure endless webs, or move a stadium roof over several hundred feet. In such cases, the geared or coupled approach become impossible or at best extremely expensive.

Faced with these facts, Uni-Systems chose a combination of the geared and friction methods to rotate the encoder shafts on our most recent stadium roof project, Reliant Stadium in Houston, TX. Reliant Stadium has a bi-parting roof, where each of the roof panels rests on five carriers per side, each carrier on two driven 36” wheels. Each roof side has multiple encoders, which we will return to shortly.

The individual encoder shaft was fitted with an aluminum pinion gear that directly engaged the 39” pitch diameter bull gear mounted to the side of the drive wheel. This approach was chosen to move the slippage point from an encoder-mounted friction wheel to the friction point between a wheel carrying a nominal load of 130,000 pounds and the guide rail. The roof drive wheels are turned by VFD-controlled electric motors whose ramped start-stop feature eliminates associated slippage.

What we still had to contend with, was the drive wheel manufacturing tolerances. While they had to be very high, to avoid introducing differential-load strain on the AC motors, they could not be high enough to prevent some error accumulation over the 255’ travel of each roof panel.

To remove the need for a trial and error approach to finding the correct ratio between encoder shaft rotation and traveled distance for each encoder wheel, we included a teaching sequence in the PLC/HMI programs. The operator could now chose a “learning” sequence during the opening of a roof panel. The system would now use the recorded “actual travel” together with the known distance between proximity switch controlled end points to calculate the necessary individual encoder correction factors, and enter them into the program. Calibration done!

Since “the Show must go on” and since downtime or positioning-induced failures are unacceptable in a moving roof with tens of thousands of spectators located below it, we designed the system with multiple levels of redundancy. In the encoder system this meant that instead of one encoder per roof side, which is all that the logic would require, we used three. Two encoders would not be enough, since that would leave us with only one, if the other one failed, and that would leave us back at depending on the “word” of just one encoder.

With three encoders we could have a failure and still have two left to provide redundancy. The encoders in each group are programmatically designated 1 (the boss), 2, and 3. During each PLC scan, the encoder registers are crosschecked; if encoder 1 agrees with encoder 2 (within the programmed tolerance), then the value of #1 is accepted as the position. Number 3 is still checked for compliance as well. If #1 does ***not*** agree with #2, then it is tested against #3; if this test succeeds, then #1’s value is chosen and #2 is flagged to the operator as being outside tolerance. If the test failed, then the test is repeated between #2 and #3, if this test succeeds #2’s value is chosen as the roof side position and #1 is flagged. If the test fails, all encoders are flagged, and the roof stops. After replacing the encoders, the actual positions can be reentered into the count registers from numbered stainless steel markers located along the guide rail.

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