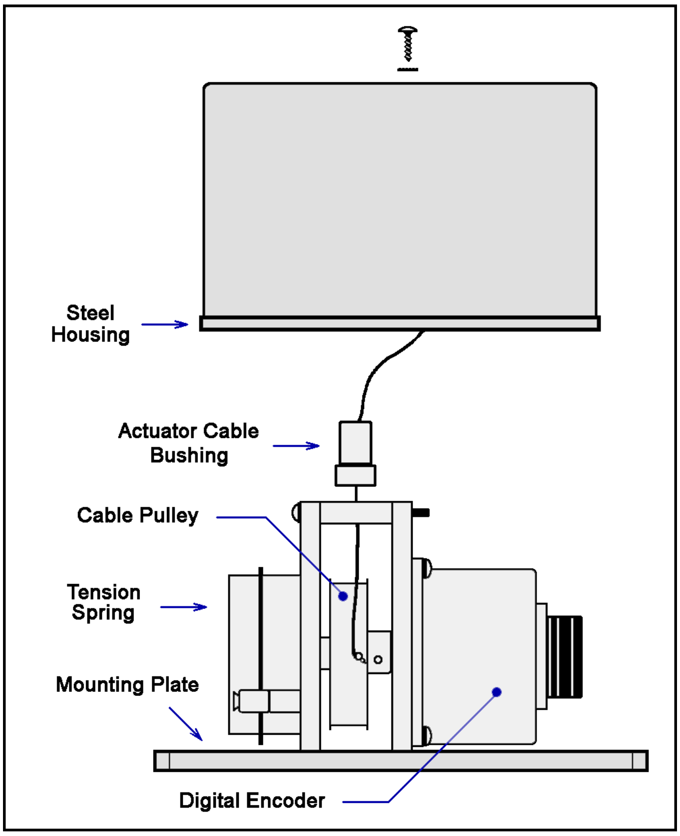
The Position / Velocity Encoder

Dennis B. Loar
Tymac Controls Corp.
Franklin, New Jersey

The position/velocity transducer provides the initial data for any type of process monitoring or process control on a die casting machine. The speed, accuracy, and reliability of this device determines the quality of the monitoring or process control function for the machine. On a closed-loop controlled die casting machine, the quality of input from this transducer can effectively determine the productivity of the machine as well as the quality of the parts produced on it. This article
has been researched and written with the intention of better understanding this critical input technology and the hardware implementation of that technology.

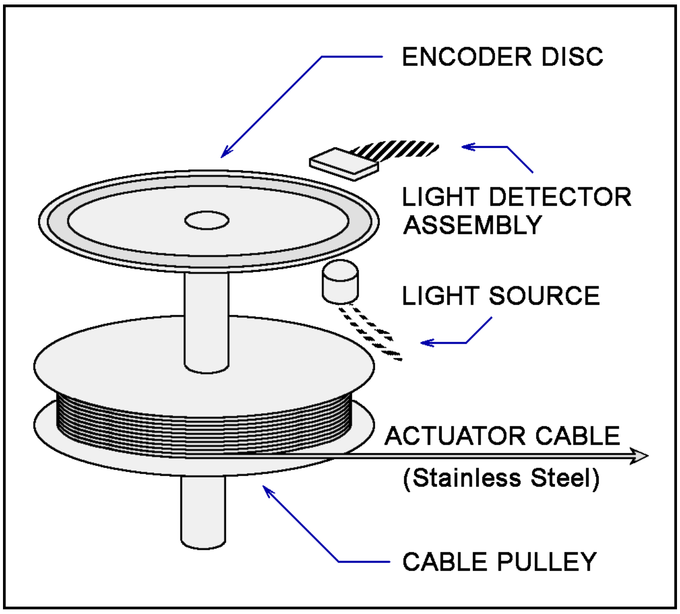
Many different designs and types of position/velocity encoding units have been evaluated because these devices provide that fundamental input data to all types of systems that we manufacture and service. We needed to determine the best position/velocity input device because the speed, accuracy, and reliability of the velocity/position data input directly affects the performance of all of our products. We defined three criteria for evaluation of different velocity/position encoding units:

1. The sensor must be fast and accurate over a wide range of conditions. It must be able to handle both long and short stroke lengths, and plunger speeds exceeding 500 inches per second (ips).
2. The sensor design must be simple and easy to access. A complex sensor is both difficult to repair, and expensive to maintain.
3. The sensor must be reliable in the demanding die casting plant environment.



Cable-actuated digital position encoder.

In the early 1980s, string potentiometers (string pots) were used for position/velocity input, and they showed poor performance, as they were easily broken when the cable was freed for any reason. Realizing the need for a



Simplified diagram of encoder operation.

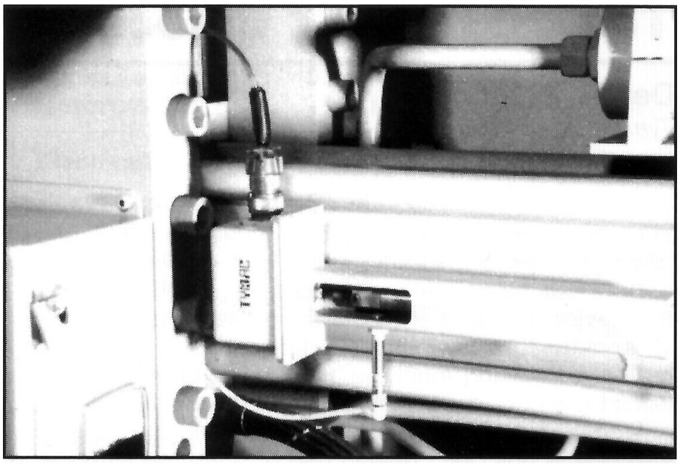
better alternative, we tested every known alternative input technology, including magnetorestrictive sensors, rack-and-pinion encoders, and piston-rod encoders, and found that the position/velocity encoder technology that best meets our three criteria is the Cable-Actuated Digital Position Encoder. All other types and designs of sensing units have been found lacking in one or more of the criteria.

The Cable-Actuated Digital Encoder - How It Works

The digital encoder converts analog signals corresponding to the phase of light intensity sensed by an optical encoder to provide two signal outputs. These two signal outputs are commonly used to determine position, speed and direction. The digital signals are in the form of square waves or "on and off" pulses. The number of pulses during a given time period renders the velocity input, and comparing the relative phase of the two signal outputs provides the direction of the movement, and the position input.

The two signal outputs are produced by an encoder disk, a light source, and two light detectors. The encoder disk is a small metal wheel with slots cut into the circumference at defined intervals (see illustration). In the case of the newly-designed encoder, the standard disk is approximately 1.5 inches in diameter and has 1000 slots around the disk circumference. The light source is a small semiconductor device like a Light Emitting Diode (LED). The light source detector is also a semiconductor device that senses the analog amplitude of the light, which varies with the phase angle corresponding to position.

In operation, when a die cast machine plunger moves, it pulls the cable, and that "actuating" cable causes the encoder disk to rotate. The small slots on the encoder disk act much the same as a venetian blind, varying the light intensity to the detector. As each slot passes between the light source and the light detector, the detector sees the light through the slot. A converter converts the analog signal to a digital signal, and a pulse is generated. One full revolution of the disk provides 1000 pulses. A second detector is mounted slightly offset from the first, and it also generates 1000 pulses per complete disk revolution, but its pulses are either ahead of or behind the primary detector's pulses. The phase shift between the two sets of pulses provides direction information.

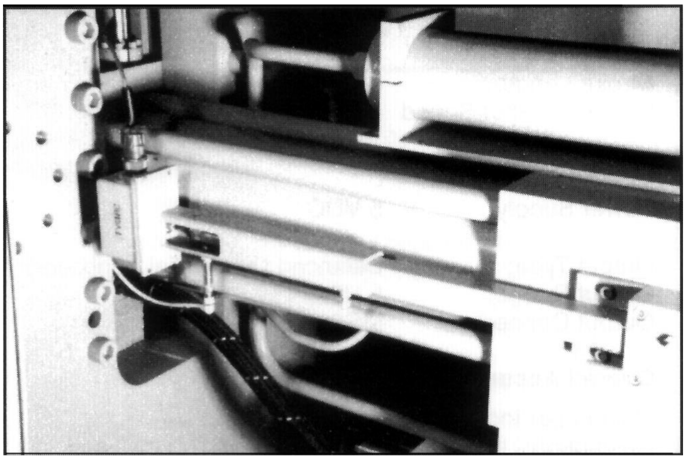


Digital encoder assembly with cable guard.

Unlike other velocity sensors, the digital encoder has no contacting parts. The encoding disk is a ball-bearing-mounted, free-spinning wheel. It spins between the light source and the light sensor without touching. Also, unlike old string pot sensors, the digital encoder has no mechanical limitations or stops. Thus, it is impossible to make a digital encoder fail by mechanically overwinding, or fast-stopping the unit. In fact, the new digital encoder can withstand over 50 Gs of acceleration. A device with no contacting parts cannot wear out, and this is a significant factor in the reliability of the unit.

Speed and Accuracy

The velocity/position measurement encoder is the true heart of any modern DCM process monitoring or process control system. This sensor tracks the position and speed of the shot plunger during the course of the DCM shot, and these measurements are the key references to which other process variables are compared and displayed. A small variation in plunger speed can be the difference between a good part and scrap. If



Encoder on machine.

the velocity/position encoder is incapable of measuring that small variation, the data collected from both the good shot and the scrap shot would look the same. Accuracy and high resolution of this critical input is the basis for all monitoring and process control in the die casting process. Thus, resolution (the number of readings sensed per inch of plunger travel) is a major determinant of accuracy as well as overall system effectiveness.

The cable-actuated digital encoder has a sensor response of 800 pulses per inch. In other words, it collects a reading of shot performance data every 0.00125 inches of plunger travel for the duration of the DCM shot cycle. This sensor response gives very high resolution for both data collection and velocity feedback, and in fact the combined resolution and response time of the cable-actuated digital encoder is unequaled by any other available die casting instrument technology today.

Simplified Design

The diecasting plant environment presents a grueling operating challenge to any electromechanical hardware. Monitoring systems, shot control systems, and shot end units are no exceptions. The position/velocity sensor must be durable as well as versatile enough to maintain accuracy and reliability in the elevated temperatures, at extreme velocities, and with the punishing shocks commonly found in the plant. Also, the position/velocity sensor must allow easy installation and minimum downtime on a wide variety of die casting machines.

The new cable-actuated digital encoder represents a simple and cost-effective solution for this demanding environment. A special aircraft-grade stainless-steel-strand cable and a pulley form the design used to actuate, or rotate, the digital encoder as the shot plunger moves forward. A torsion spring is used to ensure that the cable does not come off the pulley, to prevent any whipsaw effect, and to rewind the cable during shot return. The accuracy of the sensor is even more critical when the process control system provides real-time closed-loop control. A key requirement of effective real-time closed-loop shot control is the extremely accurate measurement data. Extremely accurate and quick measurement of the shot velocity is needed for the control system to maintain or change speeds accurately within the short duration of a DCM shot injection.

The pulse cycle of the new cable-actuated digital encoder is one pulse every 0.00125 inches of shot plunger travel, or about 800 pulses per inch of shot plunger travel. This results in a resolution and response time of **TEN TIMES** the accuracy of the next fastest available position/velocity input device on the market.

Given the cable-and-pulley actuator design of this encoder, it is the specially designed stainless-steel cable component that absorbs all wear and tear resulting from the die casting process. The digital encoder itself is insulated. This stainless-steel cable has been tested, and it does take the punishment of 50 G accelerations, even in extreme temperatures. So, when the demanding die casting environment ultimately takes a toll, it is the inexpensive and readily accessible cable that fails and must be replaced. Typically, replacing the actuating cable takes less than 10 minutes. Cable replacement is usually put on the plant's preventative maintenance schedule to eliminate unnecessary downtime and unscheduled maintenance.

The cable-actuated digital encoder design also gives this unit a compact size that provides great flexibility when installing it on a die cast machine. This flexibility allows the encoder to reliably perform on permanent die cast machine installations as well as on portable machine monitors, where ease of installation and use are mandatory.

Reliability

When measured as a percentage of attributable downtime hours, the cable-actuated digital encoder is the most reliable velocity/position encoder device available to the die casting industry today. Like any other die casting machine component, something is going to break, and over 92% of failures with these devices are attributed to breakage of the actuator cable. As previously discussed, making cable replacement a preventative maintenance item will all but eliminate failures. Less than 2% of all failures of cable-actuated digital encoders involves failure of the digital encoder itself, but complete replacement of the digital encoder transducer is also easily accomplished within less than an hour. It involves no significant machine disassembly, nor appreciable downtime, and the replacement unit costs are extremely low.

The cable used with the encoder is the result of 15 years of lab testing and field testing involving all alternatives known to us. It is the toughest composite cable that we have found, and under normal die cast plant conditions, we have seen cables last over 1 million DCM shots. Due to their low lost, we recommend replacement four time a year. Assuming a generous 15 minutes to change the cable each time, this amounts to one hour of machine downtime per year, in return for near-perfect reliability.

Conclusion

This new cable-actuated digital encoder is believed to be the fastest, most accurate, and most reliable encoder device currently available to the die casting industry. It is the only available encoding device that reliably gives resolution of 0.00125in., or 800 counts per in., in both short or long stroke lengths, at both fast and slow plunger speeds.

Shot End:	
Stroke Length:	0.1 to over 50 in.
Maximum Shot Speed:	+500 IPS
Electrical:	
Power Supply:	5VCD
Output Type:	Balanced Differential (encoder)
Output Range:	5VDC
Output Connector:	MS3102R18-1P
Overall Accuracy:	
Counts per Inch:	800
Resolution:	0.00125 in.
Environmental:	
Operating Temp.:	0 to 70C
Enclosure Rating:	NEMA 13

Digital Position/Velocity Encoder Specifications.

Installation is easy due to the simple design of the encoder unit. Maintenance is performed with absolutely no downtime penalty when scheduled into regular preventative maintenance procedures. Both installation and maintenance of these position/velocity encoders is low-cost, and users need never worry about disassembly of the cylinder for installation, maintenance, or repair, nor damage to the sensor due to cylinder rod runout or metal flakes.

Anyone considering an alternative position/velocity encoding device would do well to accurately compare performance data, maintenance cost data, and reliability statistics from companies that have used cable-actuated digital encoders in production for many years, to those of any alternative encoder. The cable-actuated digital encoder is believed to have no rival in performance, operating cost, nor simplicity of design for maintenance.

Tymac Controls Corp

127 Main St. Franklin, NJ 07416 Phone: (973)827-4050 Fax: (973)827-9247 us@tymac.com (10/2002)

US Patents: 3,911,419, 3,878,375, 4,094,490, 4,249,186 4,383,449, 4,504,920, 4,734,869 Canadian Patent: 1-234-902 European Patent: 0 126 174