LANSCE-R INVESTIGATION: IMPROVING THE WIRE SCANNER MOTION CONTROL*

J. Sedillo, J. D. Gilpatrick, F. Gonzales, J. Power, LANL, Los Alamos, NM 87545, U.S.A.

Abstract

The LANSCE accelerator facility utlizes 110 wire scanner devices to monitor the accelerator's charged particle beam. The LANSCE facility's existing wire scanner control systems have remained relatively unchanged since the LANSCE accelerator became operational in the 1970's. The evolution of motion control technologies now permits the development of a wire scanner motion control system that improves in areas of energy efficiency, precision, speed, resolution, robustness, upgradeability, maintainability, and overall cost. The purpose of this project is to research the capabilities of today's motion control products and analyze the performance of these products when applied to a wire scanner beam profile measurement. This experiment's test bed consists of a PC running LabVIEW, a National Instruments motion controller, and a LEDA (Low Energy Demonstration Accelerator) actuator. From this experiment, feedback sensor performance and overall motion performance (with an emphasis on obtaining maximum scan speed) has been evaluated.

INTRODUCTION

The Los Alamos Neutron Science Center (LANSCE) accelerator facility wire scanner system utilizes actuators and electronics that have existed since the accelerator's inception. The existing control system utilizes a motor drive that was developed and manufactured at LANSCE and is controlled directly by the LANSCE Operations Computers through LANSCE's Remote Instrumentation and Control Equipment (RICE) system. No feedback is employed for actuator positioning. Instead, wire scanner actuator position sensors are utilized to gauge the health of the actuator mechanics. The purpose of this study is to evaluate a previously utilized actuator, motor driver, and motion controller from the Low-Energy Demonstration Accelerator (LEDA) experiment to evaluate actuator movement performance and feedback sensor position accuracy. Furthermore, a resolver was also added so that its performance could be determined on this actuator.

SYSTEM DESCRIPTION

In order to evaluate sensor/actuator performance, we assembled a system utilizing a LEDA (Low Energy Demonstration Accelerator) wire scanner actuator powered by a Parker GT Stepper Drive. The motion was controlled by a PCI-7344 motion controller card within a Windows-based PC running LabVIEW. The

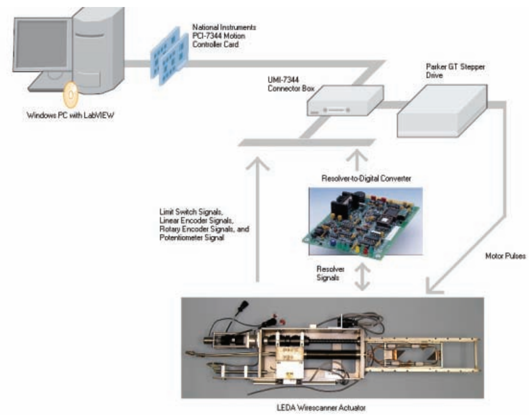

Figure 1: System Schematic

potentiometer and linear encoder maintained their original configuration of being coupled to the translational movement of the actuator. Furthermore, the rotary encoder maintained its original position as being coupled to the shaft of the stepper motor. A resolver was later added behind the rotary encoder and, like the rotary encoder, was directly coupled to the motor shaft. Details are shown in figure 2.

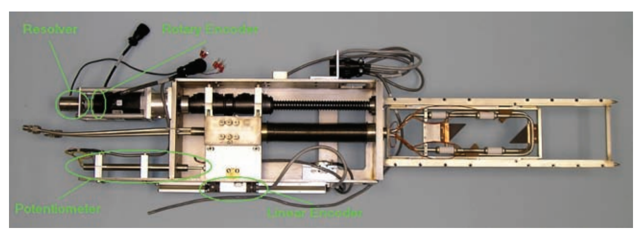

Figure 2: LEDA Wire Scanner Actuator with sensors highlighted

POSITION SENSOR TYPES UTILIZED

Linear Encoder

This sensor measures linear displacement through the use of a patterned film, two LED's, and two infrared photosensors. The pattern blocks the LED light in such a way that a quadrature signal is output from the sensor. This signal is used by the motion controller to detect sensor movement and direction. Although this sensor has a high degree of precision, the presence of semiconductor components in its manufacture increases its susceptibility to damage from ionizing radiation.

*Work supported by the United States Department of Energy.

Rotary Encoder

This sensor functions in a manner similar to the linear encoder above, but is designed to measure angular displacement. Like the linear encoder, this sensor is highly susceptible to damage from ionizing radiation.

Resolver

Resolvers are sensors that are similar in design to a typical electric motor. In order to be useful for angular position measurement, these sensors must be coupled with a Resolver-to-Digital (R/D) Converter. When connected to an R/D converter, a resolver-based system is capable of generating position signals similar to that of an encoder. Furthermore, a resolver's R/D converter may be placed over 150ft away from the resolver, thus allowing the R/D converter's semiconductor-based components to be placed in areas that are shielded from the damaging effects of ionizing radiation.

Potentiometer

This type of sensor is typical of what is used to measure the wire position of the wire scanner actuators at LANSCE. Variations of the shaft of this potentiometer result in a voltage variation that, once read through an analog-to-digital converter, may used to measure wire position. These sensors have proven to be very resistant to the effects of ionizing radiation.

FORWARD SCAN: SENSOR COMPARISSON

We first evaluated all four sensors together in order to determine their relative performance. The optimum result of this test would be a one-to-one relationship between the commanded position and the measured position. Throughout their 119-mm scan, all sensors appear to have made very linear measurements. Furthermore, all sensors values appear to be very close to the commanded position value. However, more details emerge when the error of these sensors is plotted as shown in figure 3. This figure depicts how each sensor has deviated from the commanded position. As is evident above, the linear encoder had the least deviation primarily because it was the sensor used for the actuator's feedback. Our reason for choosing this as the baseline feedback position sensor was because it was directly coupled to the motion of interest and had resolution exceeding that of the potentiometer-based feedback. The rotary encoder is the second best performer in this test with a maximum deviation of about 120 microns. In third place was the resolver, which followed the path of the encoder for most of the scan and then began to deviate by about 170 microns toward the end of the scan. The worst performer was the potentiometer, which had the most deviation.

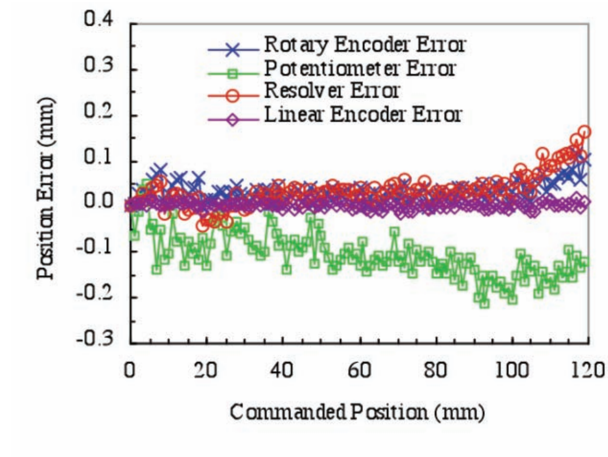

Figure 3. Deviation of each sensor from the commanded position

FASTEST 1-MILLIMETER MOVE

One of the primary objectives of this experiment was to determine how fast the actuator and its control system could perform a 1mm move (leading to a faster scan). Figure 4 shows that the fastest, most stable, 1mm move possible occurring within a timeframe of 50 ms. The criteria for this move involved a 60 mm/s peak velocity and a 3000mm/s^2 acceleration and deceleration. Increasing the acceleration and peak velocity beyond these values created an under damped response, resulting in a slower 1-mm move.

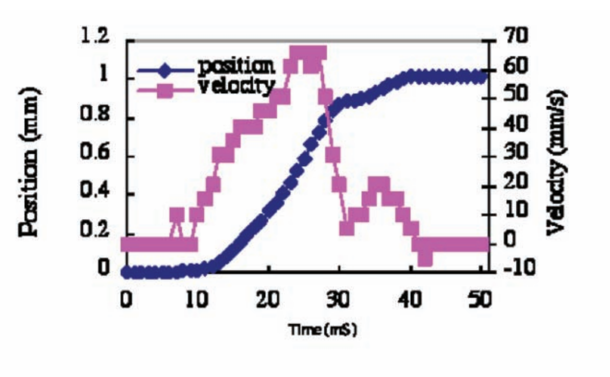

Figure 4: Velocity and linear displacement of fastest attainable move.

CLOSED-LOOP SENSOR ERROR

Table 1 presents the statistics of the error (arithmetic difference between commanded position and measured position) of each sensor when used as the feedback sensor. The data was collected by running ten, 119-mm scans at which a position sample was taken after every 1-mm moved. In total, the dataset for each test consists of 1200 data points. "Test 1" represents the statistical results of the scans set for a 25 mm/s peak velocity and 1000 mm/s^2 acceleration and deceleration. "Test 2" represents the statistical results of the scans set for a 60 mm/s peak velocity and 3000 mm/s^2 acceleration and deceleration.

Sensor	Test	Average (mm)	Std. Dev. (mm)
Linear Encoder	1	0.0021	0.0067
	2	0.0092	0.0178
Rotary Encoder	1	-0.0004	0.0033
	2	-0.0002	0.0035
Resolver	1	0.0005	0.0108
	2	-0.0016	0.0178
Potentiometer	1	0.0007	0.0389
	2	0.0028	0.0469

Table 1: Statistical summary of the error of all sensors.

Linear Encoder

The results show that the linear encoder did not perform as well at a higher rate of speed and acceleration than it had at a lower speed and acceleration. This is evident by the increase in its standard deviation as well as the significant shift in its average value from 2.1 microns to 9.2 microns. A majority of the error associated with this sensor may be attributable to mechanical errors such as backlash, actuator fabrication errors, and perhaps, mechanical bending associated with quick movements.

Rotary Encoder

The rotary encoder appeared to perform nearly identically under both tests. A minor shift in the average error occurred, but the change was a minor 0.2 microns. This superb performance is mostly likely due to the motion controller's ability to act directly on the encoder due to its direct coupling to the motor shaft. In other words, the mechanical errors associated with (e.g. backlash) the actuator have no effect on the rotary encoder error.

Resolver

The resolver had a more significant shift in its average error than did the rotary encoder, but in general, the increased error is minor. Furthermore, the increased speed and velocity caused the standard deviation of the error to increase. This increase in error may have been caused by the frequency dependence of the resolver, from which, beyond certain accelerations, the resolver system experiences a reduction in its accuracy.

Potentiometer

The increased rate of movement caused a minor shift in average error and a minor increase in the error deviation. However, in general, the potentiometer's performance decrease is probably an insignificant one.

CONCLUSIONS

Many motion control technologies exist that have the potential to improve upon many aspects of LANSCE's wire scanner motion control system. In particular, motion feedback sensors such as optical encoders and resolvers may become welcome replacements for the potentiometer-based feedback sensor currently in use on every LANSCE wire scanner. However, since optical encoders are not highly radiation-resistant, resolvers may be employable in areas where radiation would otherwise damage a solid-state device. This study has compared the relative performance of each of these sensors and the results indicate that resolvers and optical encoders outperform potentiometers primarily in regard to positional accuracy. Deployment within LANSCE's accelerator will help gauge whether or not encoders and resolvers are capable of withstanding the effects of radiation to the extent of potentiometers.

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