Upgrades to the Fermilab Flying Wire Systems

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Abstract

Flying wire systems have been installed in the Fermilab Main Ring, Tevatron, Booster, and Accumulator to measure the transverse beam profiles. During the recent shut down many improvements were incorporated to increase the reliability of the hardware, software, and data obtained from their operation. These improvements include adding a double fork to the Tevatron systems, developing a new scintillator/photomultiplier tube combination, and a broken wire monitor. In addition an analysis of the motion control was performed to understand the frequent operational problems encountered.

I. INTRODUCTION

The Flying Wire systems have been operational in the Fermilab Main Ring and Tevatron for quite some time. The basic system has been described previously.[1] The installation of the new D0 colliding detector and electrostatic separator system has necessitated a move of most of the flying wire hardware. This presented an opportunity to upgrade the equipment and incorporate some system modifications.

Major problems existed in many areas. These areas include basic communications problems, mechanical variations of components, radiation damage to tunnel components, poor diagnostic capability, and equipment not meeting latest upgrade specifications.

In addition, a complete test system has been assembled incorporating a laser to simulate beam. This will allow us to test new ideas as well as provide a repair facility for failed components.

II. SYSTEM UPGRADES

A. Motion Control

The motion of the wire through the beam is controlled by a microprocessor chip set. This chip set implements a closed loop algorithm to maintain a fixed velocity vs position profile. Parameters must be set to control the feedback characteristics of this loop. The settings of most of these parameters appeared to vary widely from one installation to the others. An in-depth study was done to determine the best set of parameters for each wire. This resulted in finding the smoothest velocity profile with minimum drive current fluctuations while the wire is in motion, as well as minimum holding current with the wire at rest.

Analysis also indicated that a non-uniform tension in the neoprene/fiberglass timing belt was a major contributor to the unpredictable parameter settings. Mechanical adjustment to compensate for varying manufacturing tolerances of the belt was not originally provided. Thus when mechanical components need replacement no provision was made to allow retuning for optimum performance. By modifying the motor mount to allow a belt tensioning scheme we removed a potential non-linearity from the system.

B. Optical Encoder

The position feedback loop uses an optical encoder to provide relative position information. There are two quadrature position outputs and an index reference pulse output. The index is used during a reset of the system to determine a fixed reference point from which all angular measurements and linear projections are calculated.

These encoders are affected by radiation in two ways: 1) a false indication of index position is occasionally seen during high accelerator losses and 2) the index pulse totally disappears after only a few months of continuous use in the tunnel. The manufacturer has evaluated, and repaired, many units and reports the failure mode as a loss of the index track light emiting diode (LED) and receiver. These items are in plastic packages and apparently darken with exposure to radiation. The quadrature track LEDs and receivers have an automatic gain circuit and can accommodate some darkening; however we as yet do not know their approximate lifetime.

To eliminate both index related problems we have installed an inductive proximity detector in parallel with the encoder. A .075" dia. copper target was installed on the main drive gear and aligned to coincide with the optical index. Both devices work in parallel when the optical index is available with the proximity detector providing a gate window for the optical index. The system is switched to allow using either device independently or in the gated mode.

C. Loss Monitors

The primary detectors that have been used in the past were the so called "Elias Cans" and "Paint Cans". Both designs used a photomultiplier tube (PMT) immersed in a scintillator oil. The Elias Cans suffered from too high a conversion efficiency resulting in easily saturated tubes. Recent modifications to the Elias Cans included blinding the PMT

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from the scintillator and extending the can to move it radially away from the loss shower. A major problem with both detectors has been the occurrence of leaks in the containers. All the scintillator oil detectors have since been removed from the system.

New PMT and plastic scintillator detectors have been installed at all of the flying wire locations. The new PMT uses a lower resistivity S-20 photocathode material. This results in a higher sustainable signal and yields good signal quality with the high voltage set at 750 volts. They should work well for higher intensity beam during collider operation.

Plastic paddles replace the mineral oil and leaky containers. The paddles are 1/2" thick and subtend a 180^o angle about the beam pipe to provide a uniform and smoother signal from losses created by the wire's motion through the beam. The PMT is mounted on the end of a 18" plexiglass extension to remove it from the primary shower.

D. Broken Wires

The key to obtaining reliable profile data is to have an intact wire. Two improvements have been incorporated into the Tevatron wire systems. A dual fork has been designed and installed that provides two wires 180^o apart within the can as shown in Figure 1. In the event a wire fails, the second wire can be rotated into position and used immediately. In order not to affect the motor's inertial loading, the new dual fork has a moment of inertia equivalent to the original single wire mount fork. This was achieved by fabricating the dual fork assembly from titanium. The original fork had been made from stainless steel.

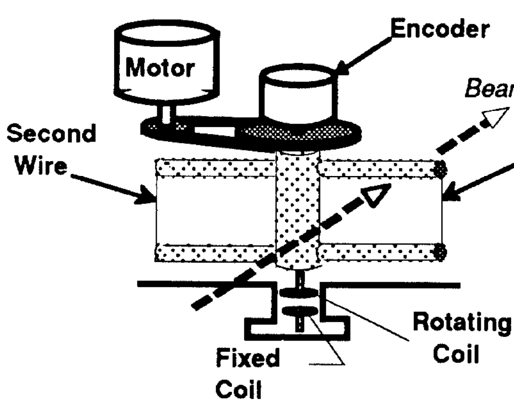

Figure 1. Tevatron Dual Fork Detail.

The second improvement is a broken wire monitor. A small switch is built into one end of the wire mounting printed circuit board. Normally the wire is in tension and the switch is open. If the wire breaks the switch closes completing a circuit that includes a 33 microfarad (first wire) or 47 microfarad (second wire) capacitor. The change of impedance is sensed through a set of coils wound on Teflon bobbins in the vacuum enclosure. The coil connecting the switches to capacitors rotates with the fork. The pickup coil is fixed and outputs through a vacuum feedthrough. Two status bits will be provided to the diagnostic application program to indicate the health of each wire.

E. Communications

Host communication is provided through a Fermilab-designed VME board designated the V080. This board contains a 68008 microprocessor. A problem has been identified in its arbitration scheme that allows conflicts to occur when this board is a participant in interrupt handling. The immediate fix was to eliminate interrupts in favor of a polling scheme. However there is a major disadvantage to this fix. The communication process moves large buffers of data after each measurement. The current scheme encounters many delays causing other programs to exhibit problems. Future work will be required to speed up data transfer.

III. OPERATION AND MAINTENANCE

A. Console Control

New control programs (diagnostic application pages) have been implemented that provide diagnostic information in an operator-friendly manner. The initial display shows the basic status of all the flying wire systems at a glance. Detailed displays of specific parameters for each wire are available on a subpage. These subpages allow the operator to modify motor drive parameters and settings of the mechanical aspects at each installation.

The procedure to reset a wire is now simplified by an interrupt field on the diagnostic application page. The software determines if the motor control board and position scalar board agree on the current wire position. If a difference is noted the wire is rotated one complete revolution and the new reference is noted. If the reference was not found on the first revolution a second revolution in the opposite direction is performed. The motor control chip set is then instructed to return to a parking position based on the new reference position.

Another new feature of the diagnostic application page allows the setting of the real time clock in each VME chassis. The real time clock is used to time stamp each fly's data for future evaluation. We now have a simple method to coordinate the time setting on each system.

A display of the boards present in the VME system chassis is now available using a subpage of the diagnostic application page. There are no longer two loss monitors per system for each of protons and antiprotons. Therefore some digitizer boards will be removed. The system now allows these boards to be removed and provides a mechanism to inform the operator that they are not installed. An additional benefit of this feature is that we now have an easy way to verify the addressing scheme within the chassis.

B. Test System

A complete collection of flying wire system parts has been assembled in our laboratory. We can now test the mechanical and electrical components in a working environment.

We have incorporated a visible laser to simulate beam and look at scattering of the laser light into the standard PMT mounted directly on the end flange. The laser is a 670nm, 5mw lasing diode. It runs on 5 volts and is activated during a fly. Preliminary results are well correlated to the actual size of the laser beam.

The construction and use of this test system has led to the discovery of and solution to a few problems already. It will serve as a test bed for new ideas and software development.

C. Future

Six wire systems are installed and will be made operational in the Accumulator Ring of the Antiproton Source. Two of these wires were originally designated for experiment E760.[2] These two wires are operationally similar to the Main Ring and Tevatron wires except they rotate a full 360° for each fly. The remaining four wires will incorporate a secondary emission readout capability.

IV. ACKNOWLEDGMENTS

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V. REFERENCES

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