MECHANICAL DESIGN AND EVALUATION OF THE MP-11-LIKE WIRE SCANNER PROTOTYPE*

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Abstract

A wire scanner (WS) is a linearly actuated diagnostic device that uses fiber wires (such as Tungsten or Silicon Carbide) to obtain the position and intensity profile of the proton beam at the Los Alamos Neutron Science Center (LANSCE) particle accelerator. LANSCE will be installing approximately 87 new WS in the near future as part of the LANSCE Risk Mitigation project as replacement of many current WS. The reason for the replacement and addition of WS is that many of the existing actuators have parts that are no longer readily available and are difficult to find, thus making maintenance very difficult. One of the main goals is to construct the new WS with as many commercially-available-off-the-shelf components as possible. In addition, faster beam scans (both mechanically and in term of data acquisition) are desired for better operation of the accelerator. This document outlines the mechanical design of the new MP-11-like WS prototype and compares it to a previously built and tested SNS-like WS prototype.

OVERALL DESIGN

The overall design of this MP-11-like wire scanner, as the name suggests, is based off of our existing MP-11 wire scanner shown in Figure 1.

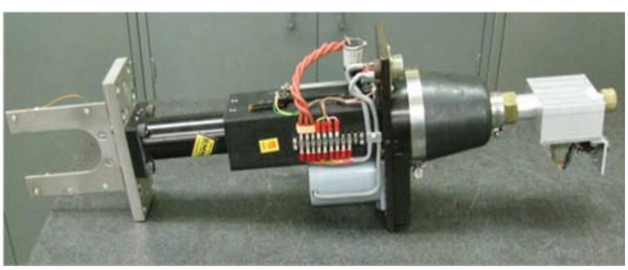

Figure 1: MP-11 Wire Scanner.

The drive system of this design consists of a motor with a gear meshed with a gear mounted on the nut of a lead screw. The nut is held in place with radial bearings which allow it to rotate in place. This rotation actuates the hollow lead screw which has the fork attached to one end and an electrical feedthrough on the other to retrieve the signals from the wire fibers. Figure 2 shows the CAD model of the MP-11 like wire scanner with its dust cover on.

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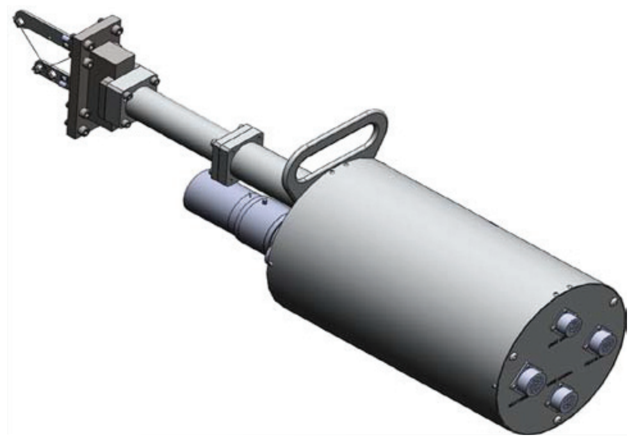

Figure 2: MP-11-Like Wire Scanner Model.

Modifications

As in the previous prototypes for LANSCE-RM, we have separated the two signal wires so that only one wire is inside the clear aperture at a time. This effectively doubles the stroke length requirement and so the whole actuator is longer.

The Ball Screw is the main component in this actuator. To improve on this design we replaced the lead screw with a ball screw. This allows for longer life without the need for lubrication.

A Motor-Resolver-Brake now replaces the old motor and potentiometer. Resolvers have no contacting pieces to wear out and have much better resolution than a potentiometer. The brake is needed since ball screws have low friction compared to lead screws that the vacuum and gravitational forces pull the wire scanner inwards when it is at rest.

The Electrical Feedthrough and Dust Cover have been largely modified as well. The electrical feedthrough is the box on the right side of Figure 1 from which the signals are extracted. In our new prototype, this was replaced with a CF1.33 flange for easier connectivity. Additionally, the dust cover, which originally was a rubber boot, has been replaced by a sheet metal cylinder to prevent decomposition due to radiation.

PROTOTYPE EVALUATION

The criteria used to evaluate the prototypes are fork stability and motion performance. For fork stability, we

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are looking for a design that maintains minimal fork vibration while in operation. For motion performance, we look for the wire scanner to meet our motion requirement of 1mm steps at 4Hz. Figure 3 shows a picture of the test set up.

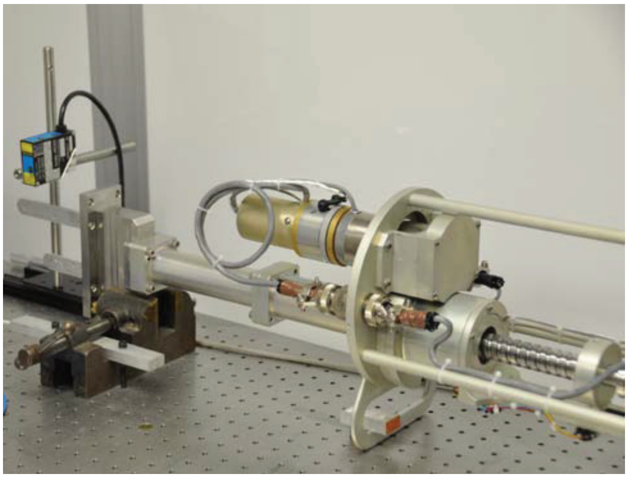

Figure 3: Test Bench Set Up.

Motion Performance

The ideal test of motion performance would be to mount the wire scanner on the accelerator structure and test it with real beam pulses; as we are in our maintenance period, this is not a possibility. For us to test the prototype in a lab/bench setting, we utilize a gate generator to simulate beam pulses of the width we want (150 µs) and at the frequency we want (4 Hz). With this gate generator and our controller, we can command the wire scanner to move at to a specific location (the beginning of the pulse) before that event happens. Figure 4 shows data taken at 4 Hz. The blue line shows the commanded location for the scanner to move to. The red line shows the actual location as read by the resolver. The purple vertical lines represent the beam pulses. Although a bit hard to see, the actuator does arrive at its commanded location prior to each beam pulse without missing any.

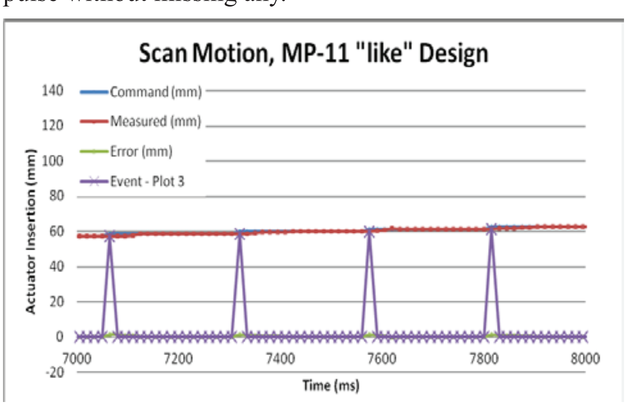

Figure 4: WS Motion Data.

Vibration Performance

The wire scanner also performed satisfactory in the vibration test. As the wire scanner is actuated in 1-mm steps at 4 Hz, the fork has a tendency to vibrate in a perpendicular direction to the direction of motion. To measure this we utilized a laser that measures distance and pointed it to the top narrow face of the fork. As the fork was actuated the laser remained in the same location with respect to the test bench. Figure 5 shows this vibration data. The blue line is the measured position while the orange line is the laser measurements (mm). This data shows an approximate vibration amplitude of about 0.1 mm. One thing to note is that this test was done in a horizontal manner while the wire scanner will eventually be mounted at a 45° angle, therefore the vibration would actually be less in the mounted configuration. Since the criterion is a stability less than 0.1mm, This actuator satisfies that.

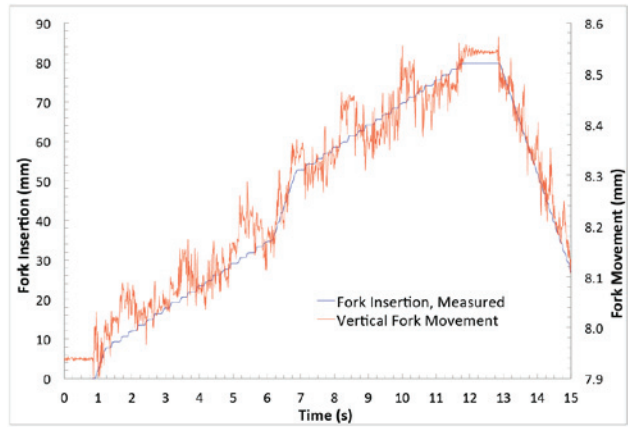

Figure 5: Fork Vibration Data.

Deflection

Another thing to be observed in Figure 5 is the slope trend of the red line. From this it seems that the fork (or actuator arm) deflects about 0.6 mm throughout the 80 mms of actuation. To investigate this further, a second set of measurements was done where the laser was mounted on a slide table and translated along with the actuation to measure the same point on the fork when it is fully retracted and when it is fully inserted. The results shows that the fork only deflects about 0.4 mm and so 0.2 mm are due to the mounting of the fork. This translates to the fork being mounted with a 0.14° slope which is hard to control.

Comparison with SNS-Like

In the Fall-Winter of 2010, an SNS-Like wire scanner prototype was constructed and tested as a possible replacement to the current wire scanners. As the name suggests, this wire scanner, seen in Figure 6, resembles the wire scanner SNS at Oak Ridge National Laboratories currently uses.

Figure 6: SNS-Like Wire Scanner.

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This wire scanner consists of a motorized linear slide table with a carriage that carries the arm and fork. The arm in this case is hollow to retrieve the signals from the wire fibers. This prototype has length and weight of 28.8 in and 34lbs respectively while the MP-11 has 26-in in length and weighs about 24 lbs. The performance of this prototype is comparable to the MP-11 like prototype and its vibration/deflection analysis can be seen on Figure 7.

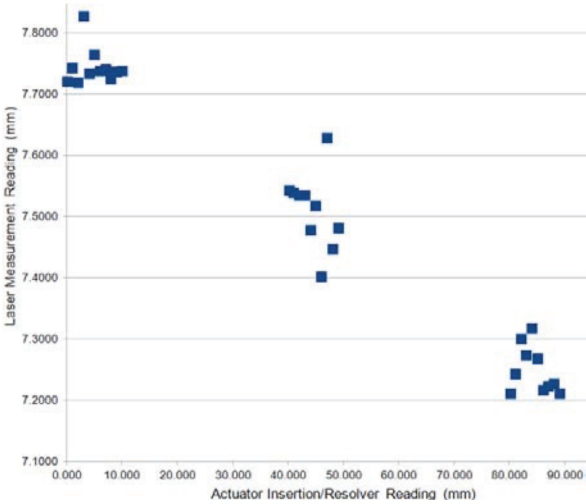

Figure 7: SNS-Like fork deflection.

At first looking at Figure 7, one would say that the fork deflects about 0.6mm throughout the 80+ mm of stroke. Looking at it closer though, one sees that the laser readings are larger at the beginning than the end. This means that there is a slant on the fork.

This fork is currently in the beam line but is expected to be retrieved soon. Once back in the lab further tests will be performed to better compare the two prototypes.

SWITCHYARD PROTOTYPE

On November 19, 2011 a prototype SNS-like wire scanner with 12" of stroke was tested on LANSCE's LXWS05 location in the switchyard. Figure 8 shows a rendering of this wire scanner.

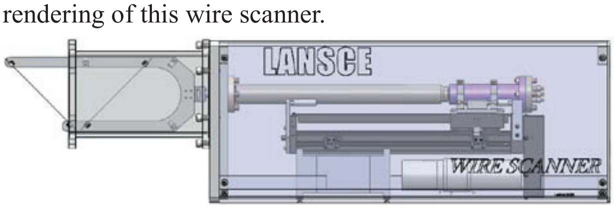

Figure 8: Switchyard wire scanner rendering.

This design features a slide table capable of 12" of stroke with a folded-over motor/gear configuration.

Motion Performance

The performance of this actuator seen with more detail in Gilpatrick's paper MOPPR080 from these proceedings [1] So I will just say that the model proved satisfactory in the 4-Hz sequential scan

Vibration Performance

As mentioned in this actuator's description, the design called for 12" of stroke; this criterion demanded a large cantilever on the fork and arm assembly. Figure 9 shows a section of the vibration data taken on this actuator. The largest amplitude seen here is about 0.15 mm which is beyond our acceptance criteria.

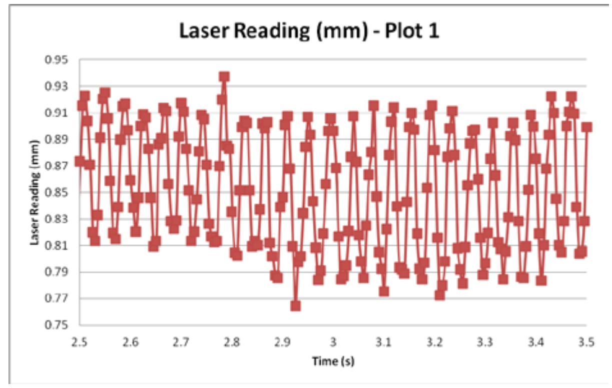

Figure 9: Vibration Test.

SUMMARY

The MP-11-like actuator looks like a promising prototype that might replace all 40 wire scanners in the linac section of our accelerator. Although both actuators proved stable enough and capable of performing the motion required, further surveying of the linear accelerator has shown that the SNS-like prototype might not fit in some areas. Although both prototypes are of similar length and height, and weight, the MP-11 like wire scanner has a smaller interface with the beam structures and that is where the most clutter is. For more information on the control system and electronics of this wire scanner please refer to these papers of this conference [1,2,3,4].

ACKNOWLEDGMENT

I'd like to thank the wire scanner team and support team at LANSCE. Without their efforts and hard work these instruments which are essential to our operation could not have been developed.

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