

DESIGN OF A PROFILE MONITOR WITH 12 INCHES OF ACTUATION FOR FRIB*

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Abstract

Actuated diagnostics present additional challenges that static diagnostics devices do not such as alignment, stability, and incorporating an appropriate drive mechanism. These challenges become even more apparent as the actuated length increases. At the Facility for Rare Isotope Beams (FRIB) we plan on using a number of actuated diagnostics devices including a Profile Monitor (AKA: Wire Scanner) with 12 inches of actuation. The Profile Monitor uses tungsten wires to traverse the beam pipe aperture to measure the beam intensity with respect to its location in the X-Y plane. This paper will detail the design of the 12 inch Profile Monitor and how it is able to overcome the stability, alignment, and drive issues that come with the 12 inches of actuation.

INTRODUCTION

The FRIB beam line has three folding segments where the beam pipe increases to up to 6 inches in diameter. This profile monitor design scans the whole aperture while maintaining the fork outside the aperture at all times. Due to cross-talk between sense wires, these wires are typically separated such that only one wire is inside the beam pipe aperture at a time. Having a fork in this configuration scanning a 6 inch aperture would result in over 16 inches of stroke which is why the task has been separated into two separate profile monitors; one would scan the horizontal “X-axis” and the other would scan the vertical “Y-axis” as well as an additional axis 45° from the vertical axis. This paper focuses on the latter which results in a minimum stroke requirement of 11.39 inches.

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DESIGN

FRIB first explored the idea of using an off-the-shelf mechanical feedthrough and it was low in cost. Upon testing a purchased unit, it was apparent that the actuator would wobble during its motion. This wobble is unacceptable to FRIB which is why a custom design was pursued.

Overall Design

The design of the Profile Monitor attempts to maintain all key components axially aligned so that the motion of actuation is as linear as possible. *Figure 1* shows the overall design of the profile monitor. Although shown in a horizontal position, this device gets mounted in a vertical orientation onto a 10-inch port of a vacuum vessel.

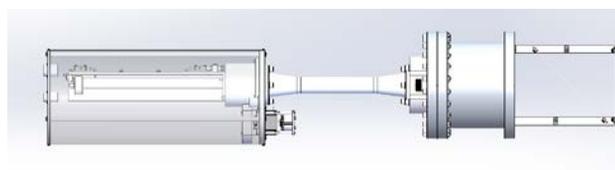


Figure 1: Overall Design.

The nipple in the front serves as a housing for the fork to retract into. This keeps the size of the vacuum vessel smaller as the flange to center distance is reduced. As it can be seen on *Figure 2*, many of the components have a piloting feature to maintain alignment.

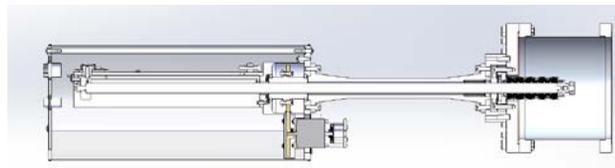


Figure 2: Section view of the profile monitor.

Fork

As previously mentioned, this fork utilizes two wires to scan the vertical axis and an axis at a 45° angle from the vertical axis. *Figure 3* shows the design of the fork.

Assuming that the first wire is tangent to the aperture of the beam pipe, and the second wire must fully traverse this 6-inch aperture, the total minimum stroke results in 11.39-inches.

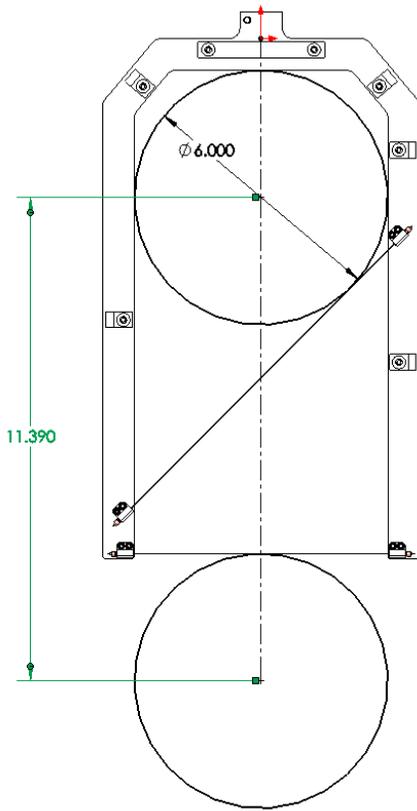


Figure 3: Fork design.

Drive System

The drive system consists of a ball-screw/ball-nut set up where the nut is driven by a motor-gear system while the screw actuates linearly. *Figure 4* shows the detailed drive system. In order to maintain stability and concentricity, the ball-nut is held in place by two radial bearings resting on features precisely machined for this purpose.

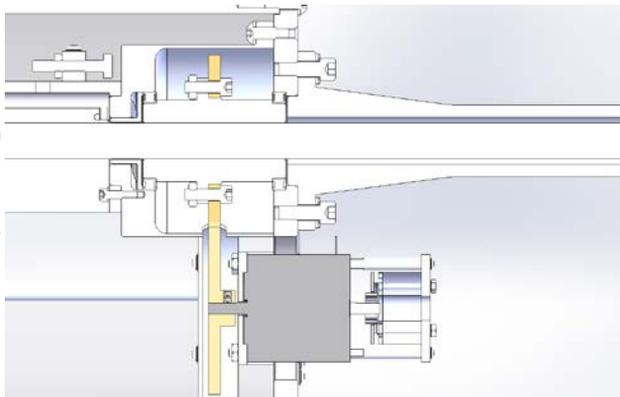


Figure 4: Drive system.

As mentioned above, this design implements a ball-screw which has very high efficiency and back-drives easily. For this reason, a brake is implemented in this design mounting directly on the rear shaft of the motor. This is a power-off brake that engages when power is cut off. This works both as a safety feature when the actuator is at rest and in the case of a power outage.

Typical actuators will have the nut driven by a rotating screw. This allows for a higher load to be actuated but also has its setbacks. Because of its length, rotating the screw would require much more torque to achieve the required speed than if it is driven by rotating the nut.

Concentricity

In order to maintain concentricity, many components are piloted into their mating counterparts. This method can be seen in the frame-to-flange interface shown in *Figure 5*. Here, the part mating to the 10-inch flange is located using two round pins (shown in green).

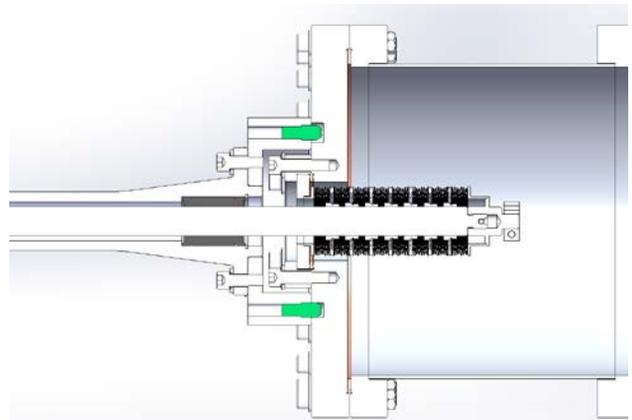


Figure 5: Frame piloting interface.

Additionally, the main frame piece (shown in the far left) pilots into the intermediate piece maintaining concentricity. Lastly, the actuated shaft is supported and guided by the linear bearing shown in grey.

Limit Switches

Part of the limit-switch bracket can be seen on the left side of *Figure 4* where the ball nut housing pilots into the bracket to maintain alignment. *Figure 6* shows a picture of the mentioned bracket. This design, includes two limit switches in the “OUT” position and one in the “IN” position. Additionally there is a guide that travels through the slot in the center of the bracket. The clearance between these two features is such that it keeps the screw from rotating while allowing it to actuate.

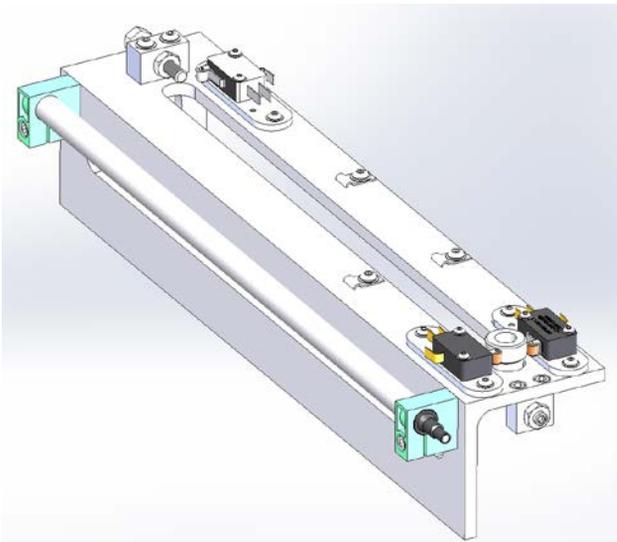


Figure 6: Limit Switch Bracket.

On the side of this bracket there is a linear potentiometer. This Potentiometer serves as position feedback to plot the beam intensity against wire position. This is also actuated by the movement of the ball-screw.

CONCLUSION

While designing an actuator for a stroke this long, under the environmental conditions of FRIB, many drive systems and components were considered. This design was based off of a design that Los Alamos National Laboratories developed, has successfully tested and is currently procuring for their LANSCE accelerator.

What makes this design work is how each component aligns with the next one to keep a concentric path for the ball screw. Additionally, the extra support from the linear bearing near the bellows allows a straight motion rather than a wobbly one seen in other designs and even off-the-shelf actuators.

FRIB plans on building at least two other variations of this profile monitor. Because of how this was designed, many parts can be interchanged between designs. This allows easier maintainability and less volume of spare parts needed in stock.