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 it's 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.

Drive System

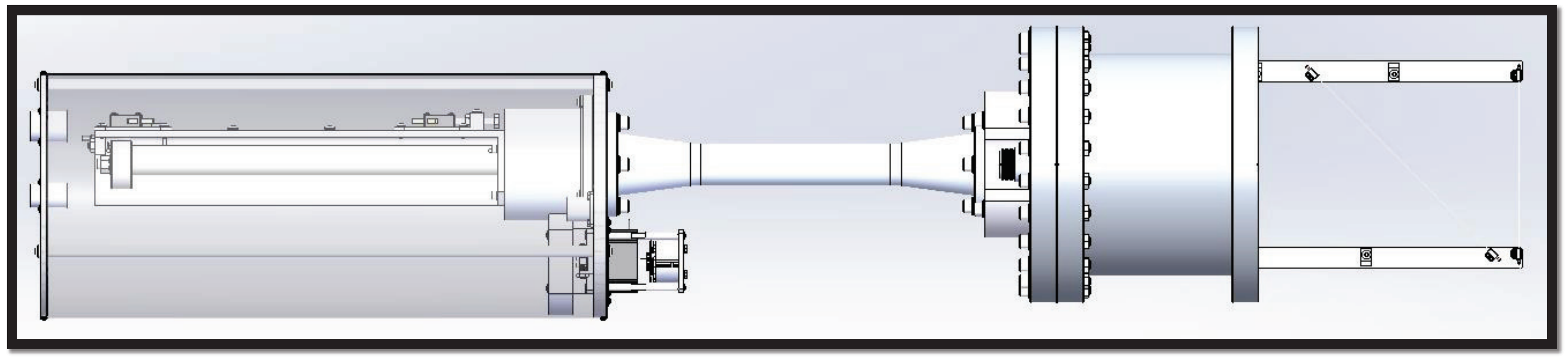
The drive system consists of a ball-screw/ball-nut set up where the nut is driven by a motor-gear system while the screw actuates linearly. In order to maintain stability and concentricity, the ball-nut is held in place by two radial bearings resting on features precisely machined for this purpose.

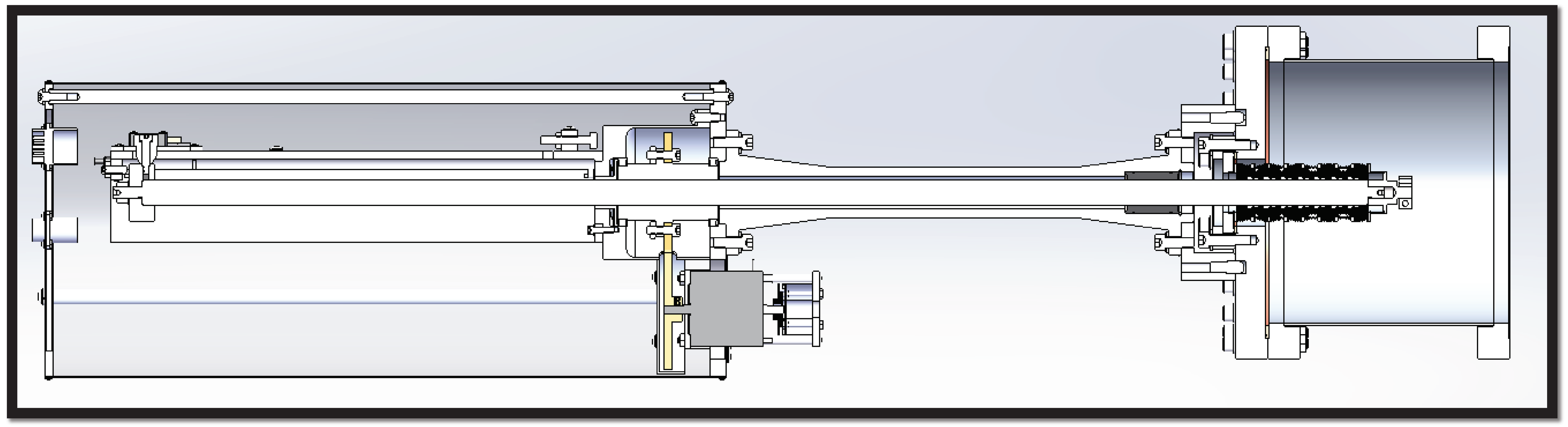
Ball-screws tend to have very high efficiency and tend to back-drive easily either due to their own weight or from vacuum forces. For this reason, a brake is implemented in this design mounting directly on the rear shaft of the motor. This is a power-off brake that engages when power is cut off. This works both as a safety feature when the actuator is at rest and in the case of a power outage.

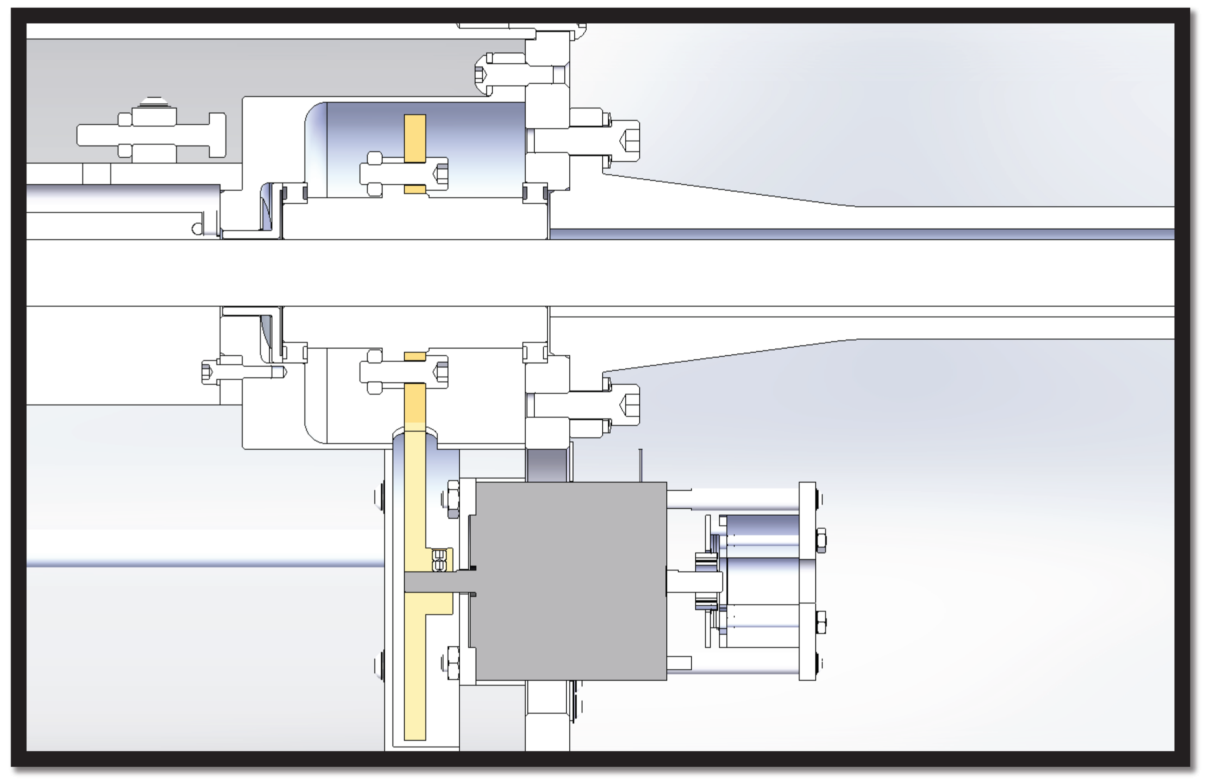
Typical actuators will have the nut driven by a rotating screw. This allows for a higher load to be actuated but also has its setbacks. Because of its length, rotating the screw would require much more torque to achieve the required speed than if it is driven by rotating the nut.

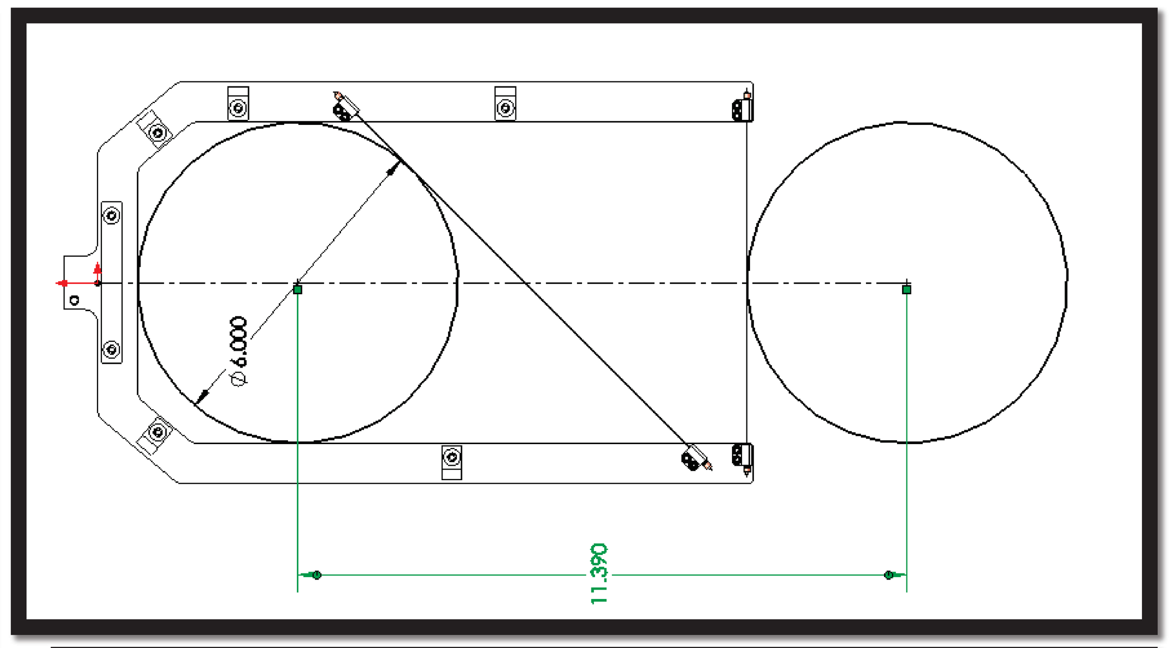
Concentricity

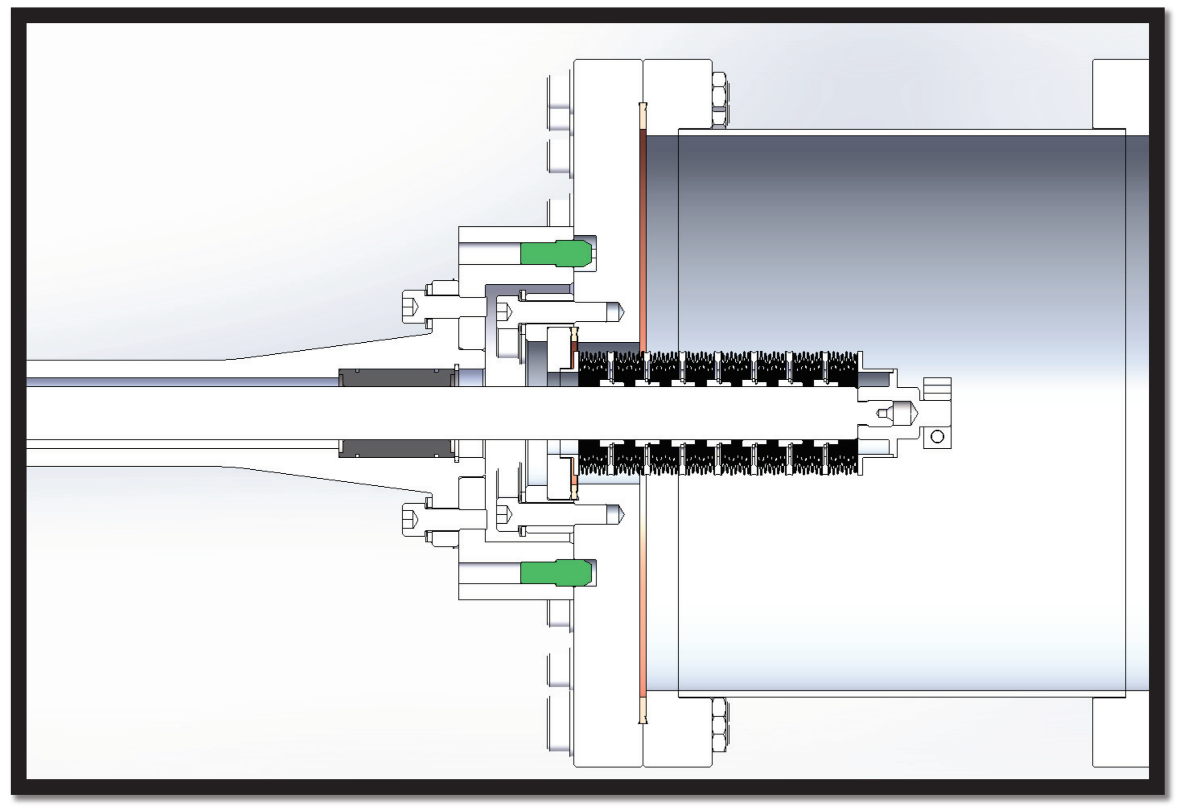
In order to maintain concentricity, many components are piloted into their mating counterparts. On the picture to the right, the part mating to the 10-inch flange is located using two round pins (shown in green). Additionally, the main frame piece (shown in the far left) pilots into the intermediate piece maintaining concentricity. Lastly, the actuated shaft is supported and guided by the linear bearing shown in grey.

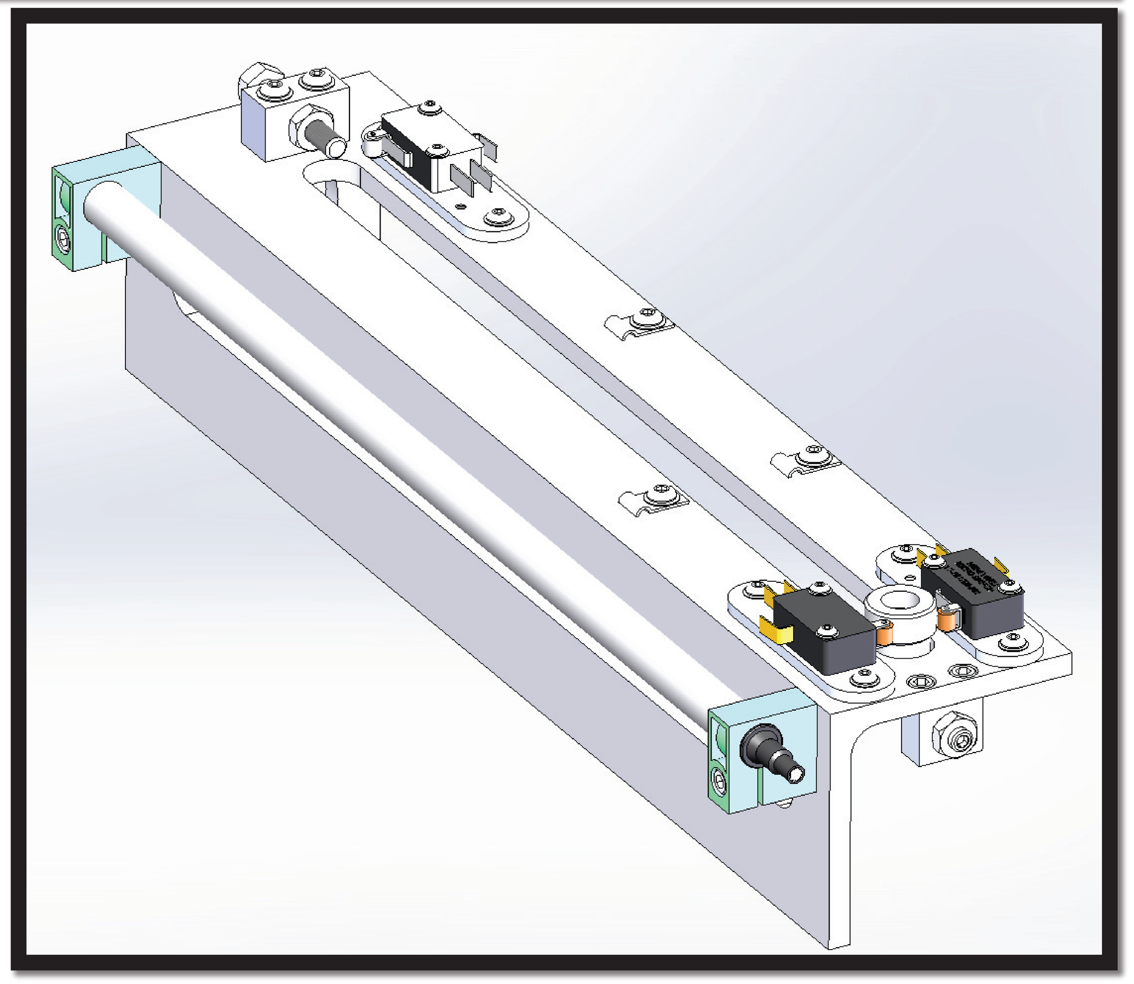












▪ Motor Torque

$$\eta = \frac{1}{1 + \frac{\pi\, d_0}{P_h}\mu}$$

Screw efficiency

where

μ = 0,0065 for SH/SHS

μ = 0,006 for SD/SDS, BD/BDS, SX, SL, SN, SND, BX, BN, TL, PN, PND

d_0 = nominal diameter of screw shaft [mm]

P_h = lead [mm]

$$\eta_p = 0{,}9\,\eta$$

Practical efficiency

$$T_t = T_f + T_{pr} + \frac{P_h\,[F + m_L\, g]}{2\,000\,\pi\,\eta_p} + \dot{\omega}\,\Sigma I$$

where

T_t = nominal torque [Nm]

T_f = torque from friction in support bearings, motors, seals, etc... [Nm]

T_{pr} = preload torque [Nm]

μ_f = coefficient of friction

$\dot{\omega}$ = angular acceleration [rad/s^2]

m_L = mass of the load [kg]

g = acceleration of gravity [9,8 m/s^2]

ΣI = $I_M + I_L + I_S$ l 10^{-9}

$$T_{pr} = \frac{F_{pr}\,P_h}{1\,000\,\pi}\left(\frac{1}{\eta_p} - 1\right)$$

where

T_{pr}= preload torque [N]

F_{pr}= preload [N]

http://www.acorn-ind.co.uk/Library/Default/Documents/ball-screw-skf.pdf

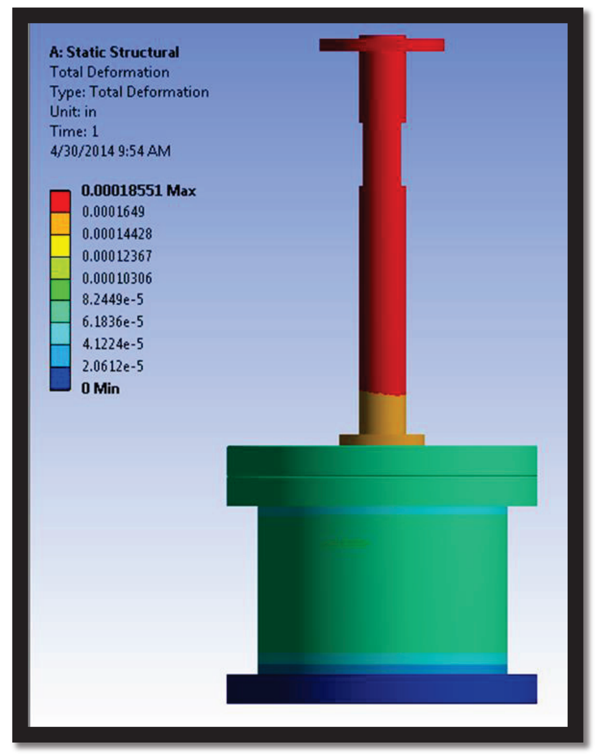
Fork

This fork utilizes two wires to scan the vertical axis and an axis at a 45° angle from the vertical axis. The Horizontal axis is scanned by an additional profile monitor mounted horizontally. 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.

Limit Switches

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. Additionally, the ball-screw housing pilots into this bracket maintaining alignment.

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.



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