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The Upgrade of a Capillary Puller

Abstract

X-rays allow us to view materials at the atomic level as a result of their small wavelengths. This capability of x-rays has allowed them to be used in various disciplines for research. Before x-rays are used they are focused using focusing optics such as single bounce mono-capillary optics(capillaries). Currently at CHESS capillaries with a large variation of dimensions are made. Our goal is to produce straight capillaries with small profile errors.

Current Setbacks:

1) Unstable tension during pull.
2) Limited accuracy of capillary straightness and profile.
3) Aligning capillary on tension stage within microns of straightness.
4) Twisted Capillary.

PID Tuning:

The PID(Proportional Integral Derivative) algorithm is used to maintain constant tension on a capillary during pull. For a PID algorithm to work perfectly, we need to find the optimal constant values for P, I, and D. The proportional term(P) is used to tune the system such that the oscillations are steady. The integral term(I) is used to reduce offset in the system. The derivative term(D) is not used in our case because the system is too noisy.

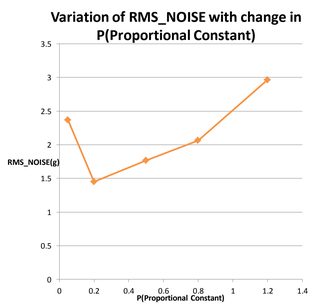
Summary of tuning process

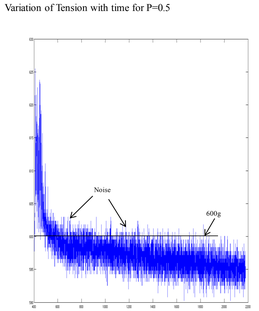
P(Proportional)	I(Integral)	D(Derivative)
P_{opt}	0	0
P_{opt}	I_{opt}	0
P_{opt}	I_{opt}	0

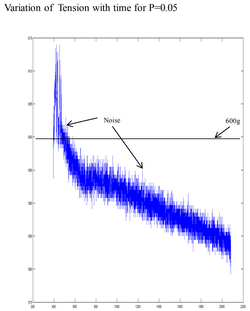
Table showing the variation of RMS noise with change in P

P(steps/g)	RMS_NOISE(g)	Range(g)
0.05	2.3712	540-590
0.2	1.4504	540-585
0.5	1.7672	595-603
0.8	2.0649	595-605
1.2	2.9657	590-605

1step=0.3µm

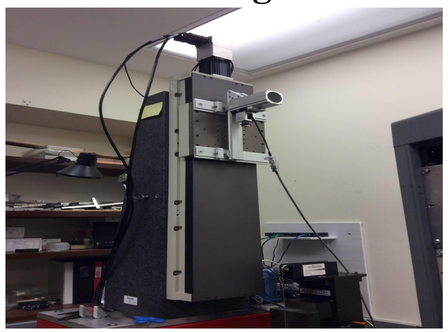






Improvements and Experiments

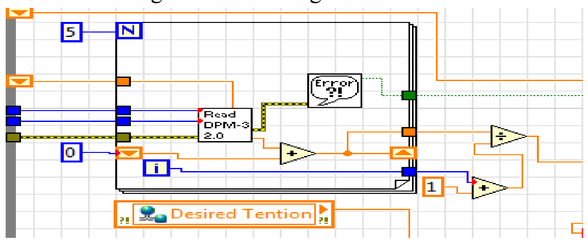
Tension Stage



	Old Stage	New Stage
Stage encoder resolution	1µm	0.1µm
Computer Software	Runs on National Instruments R.T Operating System(OS)	Soloist Controller
Tension read-out	Read from the Galil controller and R.T OS.	Galil and Soloist Controller
Pull Speed	Step motor	Servo motor
Stage straightness	50µm/300mm	-+(3µm)/750mm

Average_Tension VI

In an attempt to reduce the noise in the system a VI was written using LabView that will average the tension readout before feeding it to the PID algorithm.



	RMS_NOISE_1	RMS_NOISE_2	% diff
Case 1	2.0649	2.4553	18.91
Case 2	2.9657	3.8012	28.17

In the table above RMS_NOISE_2 represents the noise in the system with the use of averaged tension. Case 1 represents a five point average and Case 2 represents a ten point average. RMS_NOISE_1 represents noise without average tension VI. Here we observed that averaged tension produces an increase of the noise in the system. This is because it slows down the feedback response.

Future Improvements:

1) Continue the PID tuning process to find the optimum value for I(Integral term).
2) Convert the control feedback from a LabView program which runs on a windows operating system to a lower level programing language(Aerotech Basic), which will run on stage controller in order to improve overall speed of feedback mechanism.
3) Investigate cause of twist and find out ways to improve twist.

Conclusion

The steps taken here to upgrade the capillary focused on ensuring that tension was maintained at a constant level and noise reduced to a minimum.

These steps involved:

1) Procuring a tension stage with improved straightness, powerful servo motor and better position resolution.
2) PID tuning to find optimal values for P, I and D that will produce a stable system. A P value of 0.5steps/g was found to be optimal for the particular glass tube
3) Investigating whether averaged tension resulted in reduced noise.

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