UPGRADE OF A CAPILLARY PULLER

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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 vastly in various disciplines for research. Before they are used, these x-rays need to be focused to very small spot sizes using focusing optics such as single bounce mono-capillary optics. A mono-capillary (capillary) is produced using a mono-capillary puller. Currently at CHESS capillaries with large variation of dimensions are made. Our goal is to improve the pulling process and produce straight capillaries with small profile error. This paper details the improvements and research that have been carried out in trying to achieve this goal.

Capillary Puller

A capillary is made by pulling a heated piece of glass under constant tension. The glass piece is usually rotated to ensure uniform distribution of heat. The capillary puller has four main parts/functions.

- Tension stage for maintaining constant tension on glass during pull.
- Motors for rotating glass during pull.
- Furnace for heating glass and furnace stage for positioning furnace.
- Optical micrometers for measuring the profile and dimensions of capillary before and after pull.

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.

A number of measures and steps were carried out in order to solve the problems listed above. The measures included adjusting the tension readout to give averaged tension and tuning the PID system to maintain a constant tension during pull. Also a new tension stage with better straightness and resolution was purchased.

<u>Aerotech Tension Stage</u>

A new tension stage with a resolution of less than a micron has been installed. This tension stage sits on a 160kg granite block. The granite block offers rigidness to system and thus eliminates noise from the rotating motors.

	Old Stage	**New Stage**
Stage encoder resolution	1µm	0.1µm
Computer Software	Runs on National Instruments R.T Operating System(OS)	Aerotech 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

Figure.1 above offers a comparison between the old and the new tension stage

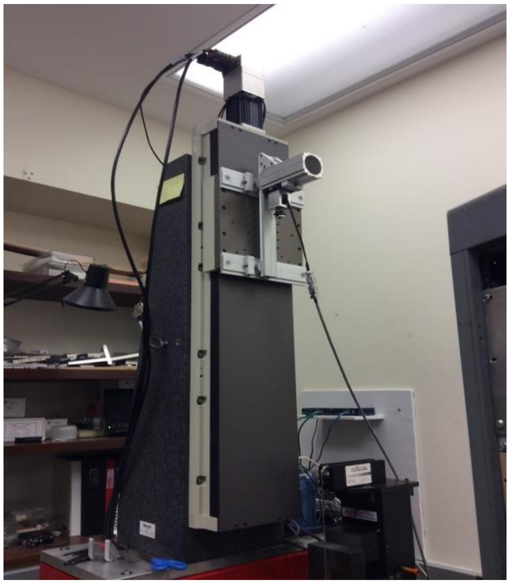

Fig.2:New Aerotech Tension Stage

Tension Readout

The capillary puller is equipped with an analog tension readout which measures the tension exerted by the puller at a rate of 25samples/second. This tension read is used in the PID system to adjust the tension on the glass. It is thus essential that this readout value be representative of the true tension on the glass. Unfortunately, the quick tension readout supplies a tension value to the PID controller that includes the noise in the system. This in turn leads to a non- constant tension. In order to reduce this problem, a LabView sub-program was created that averaged the tension from the analog readout.

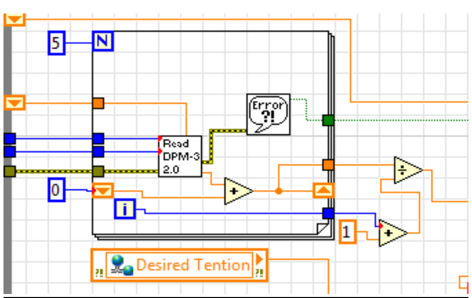

Fig.3: LabView Average_Tension sub –program.

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

Fig.4:Noise comparison with and without averaging sub-program

Figure.4 above shows the root means square noise in the system for two sets of data: One without the use of the averaging program (RMS_NOISE_1) and the other with the averaging program incorporated (RMS_NOISE_2). For $RMS\_ NOISE_2$ in case 1 the data was gotten using a five point running average, while in case 2 the noise value was gotten using a ten point running average. Also as a result of averaging there was a drop in the speed of the feedback from 25 samples/sec with RMS_NOISE_1 to 10 and 5 samples/sec in cases 1 and 2 for $RMS\_ NOISE_2$. From this data we can see that contrary to what we hoped, averaged tension readout does not produce an overall reduction of the noise in the system. This is so because it slows down the response of the feedback.

PID TUNING

The pulling process of a capillary requires constant tension. The Proportional Integral Derivative (PID) algorithm makes sure that the system stays at this constant tension. Our goal here is to find the appropriate constant for P, I and D that will give us the most stable system with constant tension. The process involves try and error. Firstly, while the I and D terms are set to zero, the value for P is varied such that the oscillations are steady. After an optimal value for P has been found, the value for I is then varied keeping P at the new optimal value and D set to zero. When an optimal value for I has been found, P and I are kept constant and the process repeated in order to get the optimal value for D. The D constant term is usually not used in noisy system because it amplifies the noise, thus making it unstable. For this reason D was set equal to zero throughout the tuning process.

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

Figure.3: PID tuning table (P_{OPT},I_{OPT} and D_{OPT} stand for the optimal values for P, I and D respectively).

The table in Figure.3 above summarizes the steps involved in the tuning process. The procedure explained above was followed and the data below collected.

P	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

Fig.4: Table showing variation of P with Noise and range of Tension achieved.

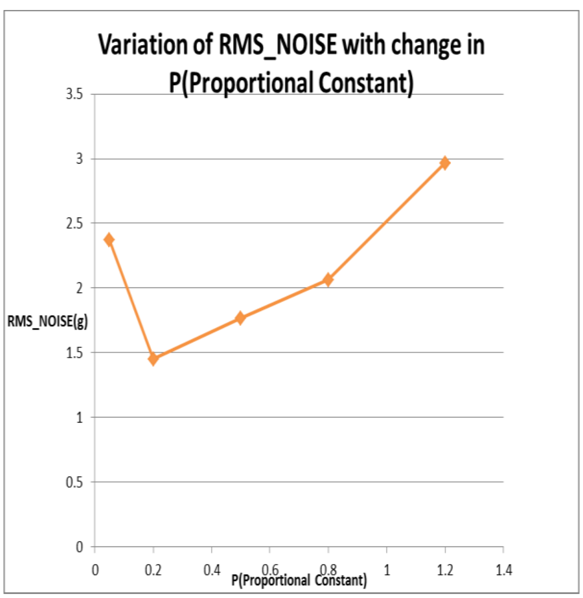

Figure.5: Plot of RMS_NOISE with change in Proportional Constant.

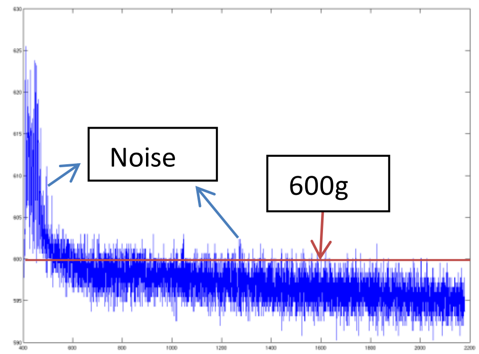

Fig.6:Graph showing Variation of tension with time

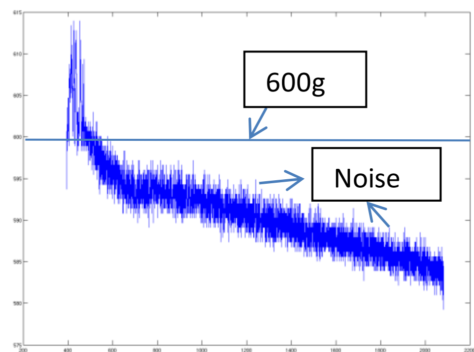

Fig.7:Graph showing Variation of tension with time

The table in figure.4 shows a variation of RMS_NOISE with changes in P. It also shows the variation of tension achieved with various values of P. The set point of tension in all the experiments here was 600g. A perfect value for P will be one that has the lowest RMS_NOISE and a small range that captures the set-point of 600g. In figures 6 and 7 we see the tension variation from a set-point of 600g with time during pull.

From the table in Figure.4, we can see that the smaller the tension range from the set point of 600g the bigger the RMS_NOISE in the system. Thus we need a value of P which gives us a balance of both. A proportional constant of 0.5 achieves this balance with an RMS_NOISE of 1.7672g and a tension range of 595-603g. The next step will involve finding the optimal value for the Integral (I) term. Due to time constraints, we were not able to gather enough data to find an optimal value for I.

Also, the current feedback is running from a windows computer program using LabView software. The next step will be using lower level language to program the feedback and run it on the stage controller. This will improve the speed of the feedback mechanism.

CONCLUSION

The steps taken here to improve our capillary puller focused on stabilizing tension during pull.

A new tension stage with improved straightness, powerful servo motor and better position resolution has been installed. It was also found that averaging the tension before feeding it to the PID controller increased the noise by 18.91% with a ten running average and by 28.17% with a four running average. While tuning the PID controller it was found that noise and capture of set-point tension were inversely related. For a tension of 600g an optimal proportional constant which captured both the set-point tension and had the lowest noise was found to be 0.5

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