Design and Test Control Approaches for the Z control of the Nano Precision stage of the Atomic Force Microscope(AFM)

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Introduction

The project aims to design and test control approaches for the 'Z' control of the Piezo actuated vertical cantilever setup of the AFM. This is carried out by a series of sections as System Identification, Controller Design and Simulation and Implementation of the controllers.

System Identification

Figure 1 shows the built model of the cantilever setup, to which the Frequency Based System identification was carried out for velocity responses for each Piezo actuator.

The obtained transfer functions are integrated to get the displacement responses for each Piezo actuator to which the controllers are designed .

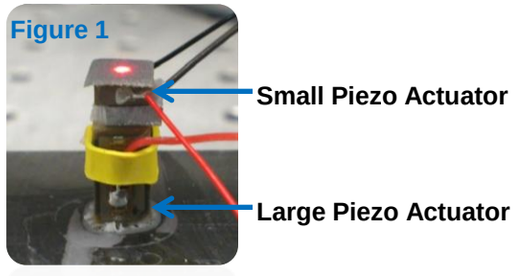

Figure 1

Controller Design

Controllers are designed for displacement response of the Large Piezo actuator meeting the criteria as follows:

- Improved Stability Margins(Gm>6dB, Pm>30^0)
- Improved Low Frequency Gains (LFG) by using the Proportional +Lag Compensator
- Attenuation of resonance at high frequencies using the Notch Filter, as shown in Figure 2.
- Avoid System Saturations, by using the anti-windup scheme as shown in Figure 3.

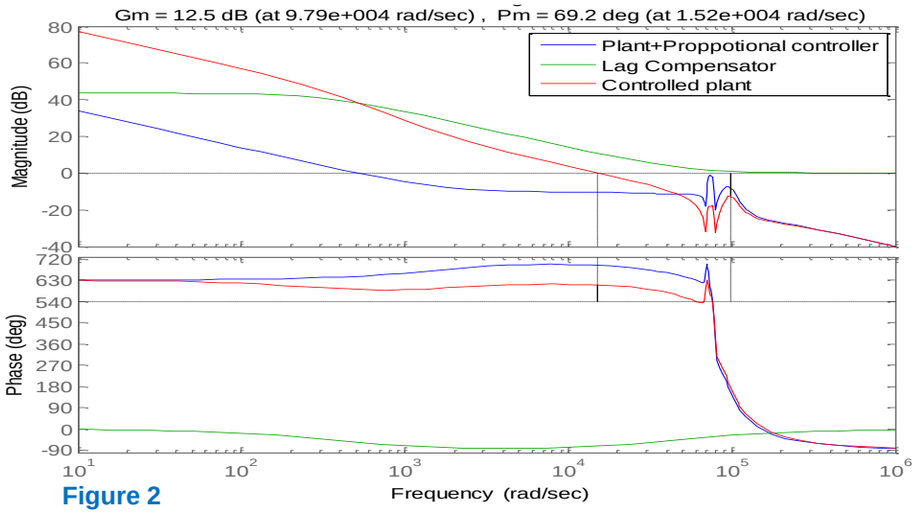

Figure 2

Figure 2, shows the bode plot for the displacement response of the controlled system (red curve) compared to system with only the proportional control(blue curve). The tuned proportional gain k_p=16000.

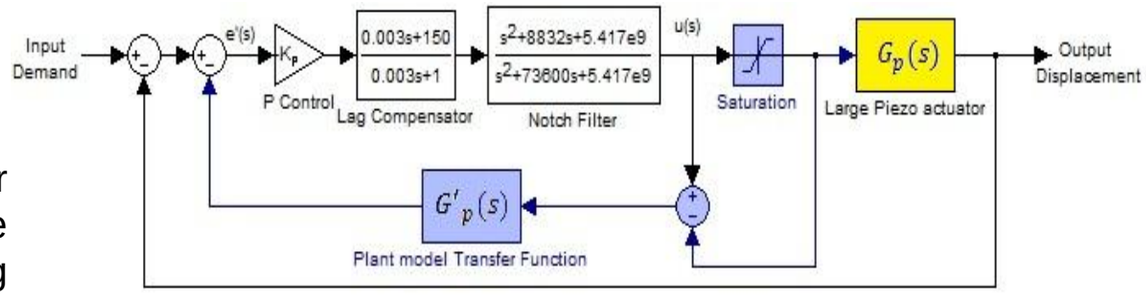

Figure 3-Block Diagram of the controlled System

Controller Implementation

The designed controllers are simulated and implemented for velocity control due to experimental limitations.

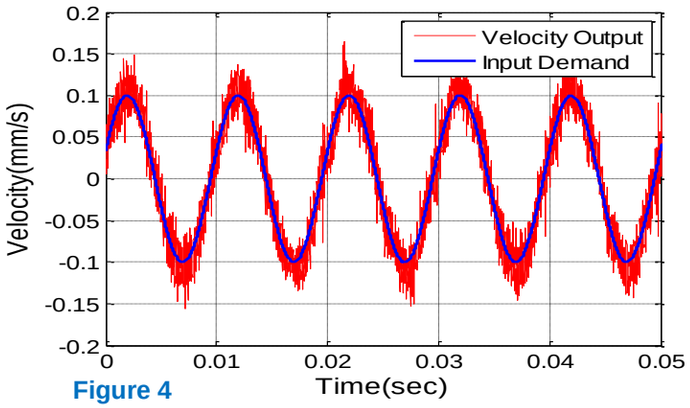

Figure 4

The best control operation was observed for a demand of amplitude 0.1mm/s at 100Hz with k_p=100, and its response is shown in Figure 4.

Control signal saturations occurring at high frequencies were reduced by the anti-windup scheme, which allowed reaching high k_p at higher frequencies.

Conclusions

It can be concluded that the designed controllers are operating as expected specially at low frequencies and controller operation could be improved by using a better amplifier so large k_p values could be reached without control signal saturations.