Analysis and Control of a Micro-precision X-Y Stage

Markos Papadimitriou

Department of Mechanical Engineering, Queen's Building, Clifton BRISTOL BS8 1TR UK

Introduction

This research project deals with a transverse dynamic force microscope (TDFM) that performs precise 3D topographical measurements. The x-y stage constitutes one of the components of the TDFM. Primary aim of the research project involves establishing velocity control of the x-y stage by designing controllers to improve the performance, that will allow biological processes to be monitored in real time. This is conducted in three stages: system identification, controller design and simulation and controller implementation.

1. System Identification

System identification is performed on the stage in the LabVIEW environment to correctly identify the dynamics of the plant by exciting the system with a sine-sweep input. The input and output data is acquired from which Bode plots are developed in the frequency domain. Figure 1 shows the X-Y stage.

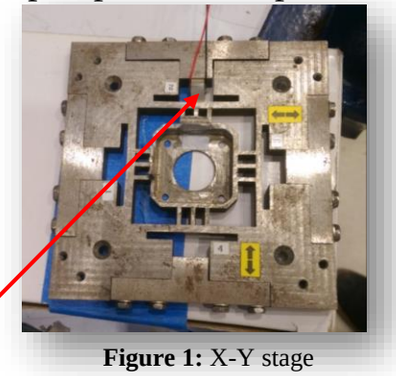

Figure 1: X-Y stage

2. Controller Design and Simulation

Suitable controllers can be designed to develop desirable velocity control of the plant, which follow certain criteria such as:

- stable margins
- high Low Frequency Gain (LFG)
- low High Frequency Gain (HFG)
- low gain at extremely low frequencies

Controller redesign had to take place in the discrete time domain, using the bilinear transformation. Figure 2 shows the final controller design and OLTF response of the plant. The designed controller is then tested in simulation, where figure 3 depicts the controller response to a 2Hz excitation, showing that it works on the modelled plant.

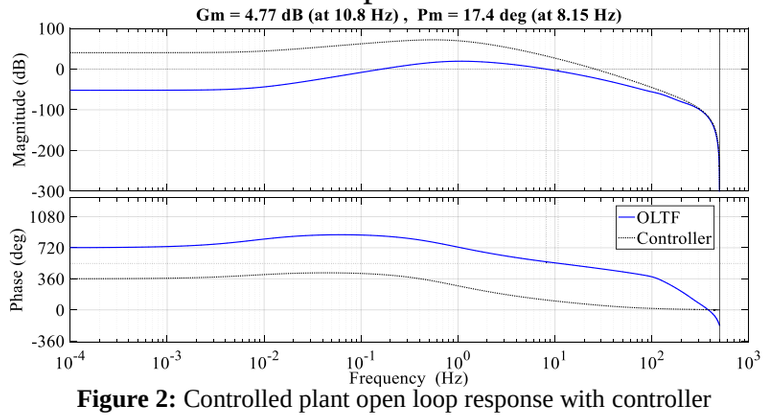

Figure 2: Controlled plant open loop response with controller

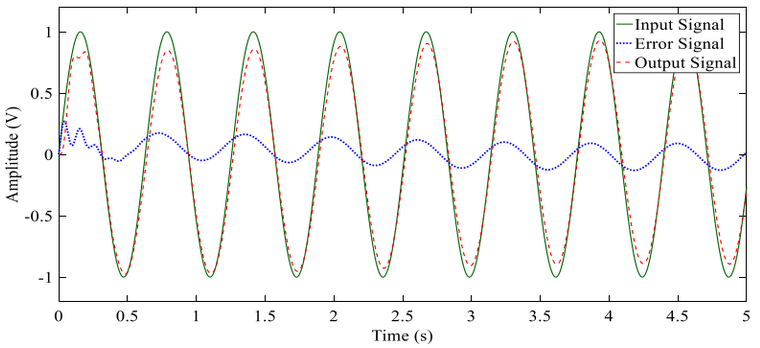

Figure 3: Time response of controlled plant with 2Hz demand signal

3. Controller Implementation

The designed discrete-time controller is implemented on the stage in real time and is tested using sinusoidal excitations.

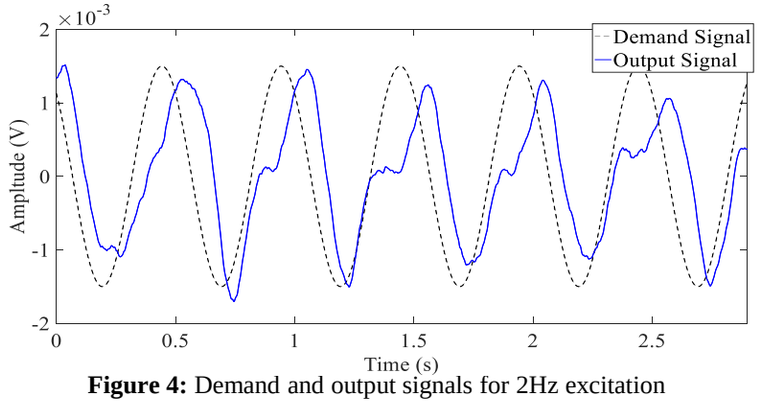

Figure 4: Demand and output signals for 2Hz excitation

Best control performance is for a 2Hz excitation, where output follows demand as displayed in figure 4. A second order Butterworth low pass filter is used to attenuate high frequency noise present while performing experiments.

Conclusions Results of controller implementation were heavily influenced by disturbances produced by external experiments. The controller designed attempted to compensate for those disturbances, which affected the results. Controller implementation results have shown that the direct discrete-time control design does achieve the targets set and plant response follows the reference signal well at the frequency designed to do so.