Analysis and Control of High Bandwidth Micro-precision X-Y Stage

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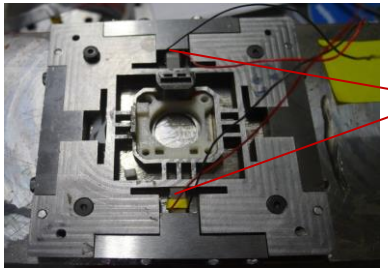
Introduction

Test subject is a Piezo-actuated X-Y stage of a transverse dynamic force microscope (TDFM). The first aim of the project is to analyse the stage to investigate the effect of preload on the resonance frequency of the x-y stage. The second aim is to design and implement a controller which provides velocity control for the stage. Process involved are system identification, controller design and finally controller implementation.

1.Analysis of X-Y Stage



Methods to investigate the effect of Preload

(1)System Identification (Experimental)

(2) Modal analysis where X-Y stage is modelled in Autodesk

Results

Experimental results shows that a preloaded x-y stage has a resonance frequency of 5920 Hz which is higher than a non-preloaded stage with resonance frequency at 5500 Hz.

Via modal analysis, a modelled preloaded stage has a resonance frequency of 6627 Hz which is higher than a modelled non-preloaded stage with resonance frequency at 6138 Hz.

2.Velocity Control of X-Y stage

System Identification

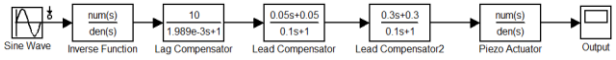
The Preloaded X-Y stage modelled via system identification previously is used to obtain an estimated transfer function whereby a bode plot of the modelled plant is generated

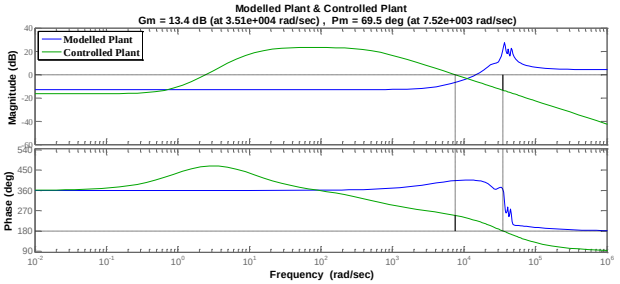
Controller targets are set as below:

1. Gain Margin $\geq 6db$ & Phase margin $\geq 45°$
2. High Low frequency gain between 10rad/s-1000rad/s and Low high frequency gain
3. Low gain amplitude at extremely low frequency
4. Attenuate Resonance Peak

Controller Design

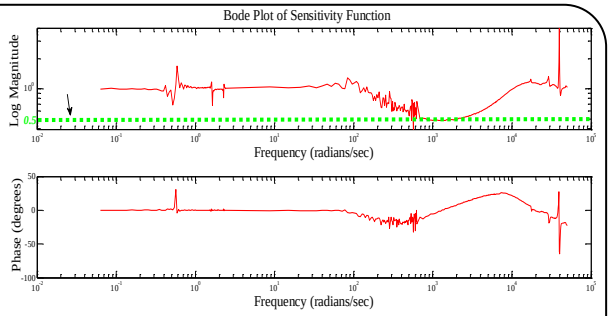
Controllers are designed and simulated as below.





Controller Implementation

Controller Implementation is carried out in D space during which a gain factor (proportional gain) was added to the controlled system and tuned to avoid instability. Gain factor is restricted at a value of 0.56. This affects the effectiveness of the controllers designed. Bode plot of Sensitivity Function is plotted to observe the performance of the controlled system.



The best error rejection was within frequency region of 100rad/s-1000rad/s with an error rejection of -6dB. However, a resonance peak is still clearly seen from the bode plot above.

Conclusions

Analysis of Stage

Results from both methods shows an increase in resonance frequency when the x-y stage is preloaded. However, modal analysis results deviate from experimental results. FE software such as Abaqus should be used for system modelling and modal analysis to obtain more accurate results as they provide an interface to model and quantify preload.

Velocity Control for X-Y Stage

Controller designed was able to meet the controller targets though not as good as expected. Failure to attenuate resonance restricted the gain factor value at 0.56 and has affected the controller's efficiency. Notch filter can be designed to attenuate resonance peak. Dynamic behaviour of the X-Y stage was also affected as on of the bolts used for preloading was replaced during the experiment.