

Waveform Determination and Positioning Control of the NanoSlider with Inertial Sliding and Stick-positioning

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Introduction

we report on the waveform determination and position-control of a metrological multi-axis nanopositioning device, we called it as NanoSlider, which is operated by piezo-based inertial method, as a sample stage for scanning probe microscopy. We have reported a nanopositioner which has long moving range and high resolution at the same time [1][2][3]. It uses inertial sliding principle and can move in the three-planar direction(XY θ). In the previous report only the experimental movement characteristics and modeling were presented. Dynamic equation formulation was performed and its validity was verified with the experiment. The experimental setup includes the three-axis laser interferometer and mirrors mounted to the body for reflecting laser beam. With the model waveform shape of the input voltage can be determined to improve the performance. The considerations taken for waveform are the oscillation at the end of the actuation step and speed of the movement. The waveform is sectioned by the four segments and each segment is polynomial function or spline curve and the function parameter is varied and the movement performance is estimated numerically with the model. Therefore suitable waveform can be determined from the simulation process. However the nonlinearity and uncertainty exists in the friction phenomena can make the real situation somewhat different from the simulation result, therefore the adaptation in the waveform should be made experimentally when applied to the real system. The modeling of the nanosl原因 includes both the stick phase model and sliding phase model. The stick phase model will be used in the control when stick and theoretical aspects can assist controlling nanosl原因 such as gain tuning and control method (stick-control mode). However it is difficult to use sliding phase model for controlling nanosl原因 in the inertial sliding mode. The reason is that it is hard to implement conventional control theory with that model because the nature of the input is very nonlinear and the motion of the nanosl原因 is quasi-static by nature. Experimental control scheme or many experimental data and its conversion to adequate experimental model will be adopted.

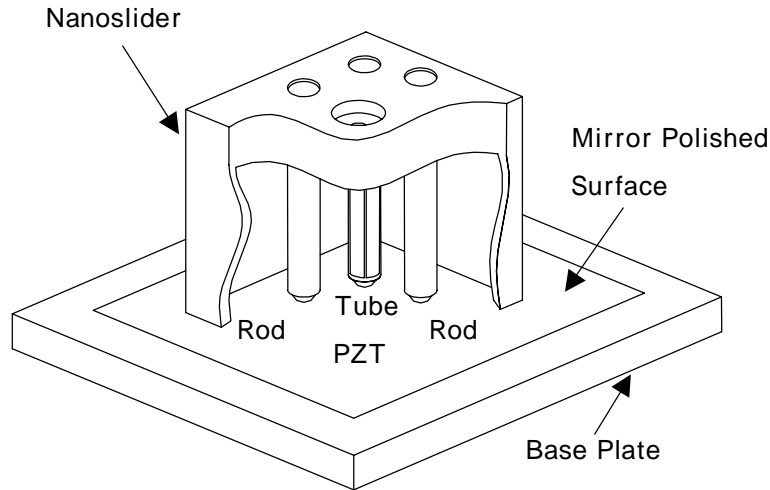


Fig. 1. Nanoslider

Experimental investigation and friction uncertainty region

Many experiments with many input waveforms, such as sawtooth input shows that under certain conditions there are significant friction condition uncertainties. The changes of the position of the nanoslider, moving path history and the motion direction(x and y) make the responses quite different in some cases and the resultant displacement is varied. This uncertain region is characterized by the input voltage and frequency : below certain voltage(about $2\mu\text{m}$) and above certain frequency(200Hz). By the small voltage input, the microscopic structure of the contacting surfaces becomes dominant and by the high frequency input (above natural frequency of the nanoslider in the motion direction) there exist so many sliding-conditions occurring and with the surface character generated by the sliding effect make the responses different (worst case is 100% error). However if the voltage is high enough and the frequency is low enough, the uncertainties become much lower(about 5%) and shows repeatable response characteristics. Therefore the modeling and simulation are based on the responses in this region and positioning control will be operated also.

Waveform determination

With the model waveform shape of the input voltage can be determined to improve the performance. The considerations taken for waveform are the oscillation at the end of the actuation step and speed of the movement. The waveform is sectioned by four segments and each segment is made by polynomial function or spline curve and the function parameter is varied and the movement performance is estimated numerically with the model. Therefore suitable waveform can be determined from the simulation process. However the nonlinearity and uncertainty exists in the friction phenomena can make the real situation somewhat different from the simulation result, therefore the

adaptation in the waveform should be made experimentally when applied to the real system. The simulation uses the modeling equations and the numerical methods are used to gain the responses. Various waveforms varying the curve parameters are put into the real system in order to examine the system responses and input waveform dependence tendencies.

3-axis positioning control

The control methods include two modes of operation which are stick-positioning and inertial sliding motion control. Basically, the inertial control mode uses the experiment-based control scheme. Experiments show that the speed of the nanoslider is nearly proportional to the input voltage and frequency and the speed is quite steady and repeatable. That means when the voltage and frequency are constant the nanoslider moves in the desired direction with almost constant speed. Therefore first the speed control can be used simply. 3-axis planar motion will be controlled simultaneously with the waveform determined and the sawtooth input also. The stick positioning starts when the desired position is near the reach of the nanoslider deflection motion and the final position-control starts.

References

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