Observations of the interaction forces between a measurement surface and a vibrating probe for a micro-scale CMM

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Abstract

The vibrating micro-CMM probe is a most promising probe to overcome drawbacks of the conventional tactile probe caused by surface interaction forces. The vibrating probe which consists of flexures, a stylus, and a tip-sphere, operates at its resonance frequency, and its phase and amplitude which can provide surface contact information is changed as it approaches to the measurement surface. This probe can measure the surface geometry with significantly low contact force, and counteract the attractive forces existing between the probe tip and a measured surface. We observed variations of the phase and amplitude of the vibrating probe caused by the interaction forces for the vertical proximity. We also investigated the condition to counteract the attractive forces which are causing the snap-in effect.

1. A vibrating micro-CMM probe

A micro-CMM which measures micro sized miniature parts has been developed. Generally, a micro-CMM has sub-micrometer accuracy for sub-millimeter sized objects.[1] In the research of a micro-CMM, the development of a probe system is very important because the accuracy of the micro-CMM is dependent of its capability. The conventional probe systems can be categorized into a tactile type, an optical type, and a vibrating type. The vibrating probe has the several merits for use as micro-CMM probe. The low probing force is achieved due to high measurement sensitivity originated from the vibrating mode. It also could counteract the interaction forces between the probe tip and the measurement surface to prevent false detections.[2]

Figure 1 shows the structure of the vibrating probe. This probe has a three-legged flexure and a stylus with a 300μm diameter ruby sphere. The stylus is connected to the center of the flexure. The first mode natural frequency of the vibrating probe was measured at 947.8 Hz and its vibrating direction is normal to the measurement surface. Especially, our vibrating probe system has an easy change feature for multiple probes due to a connection design using a kinematic clamp and magnetic balls.

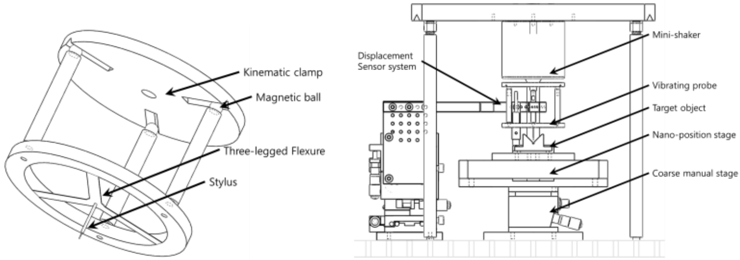


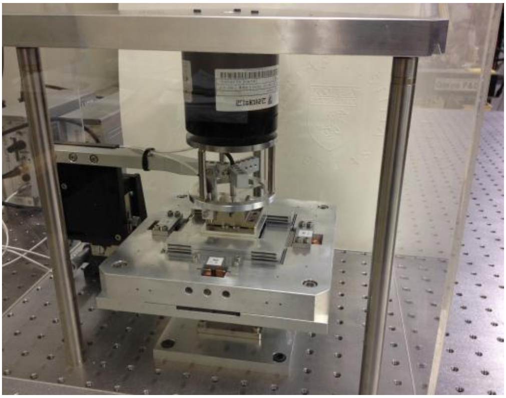
Figure 1: A three-legged vibrating probe and an experimental setup

2. Experiments and Results

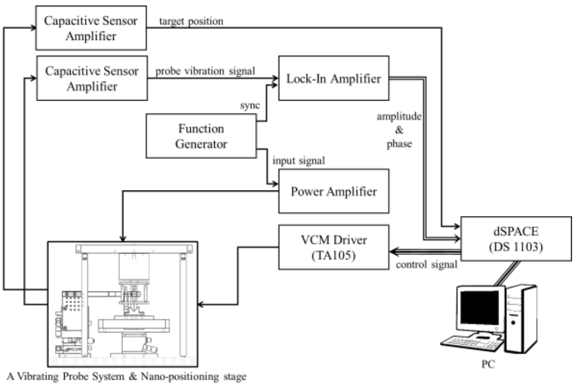
To investigate properties of our vibrating probe, we constructed an experimental set-up. We focused on the characteristics of the vibrating probe as the target object approached to the probe tip in vertical direction. For a precision inspection, the test rig requires the sophisticated displacement sensors, a lock-in amplifier, a nano-positioning stage, and a control system.

2.1 Experimental setup

The experimental system consists of the vibrating probe system, the sensor system, the precision stage, and the real-time controller. We used capacitive displacement sensors for measuring the amplitude of the vibrating probe and the position of the target object on the stage. Their resolution is tens of nanometer level. We also used the lock-in-amplifier to extract the amplitude and phase information from measured signals. For positioning a target object, we used the flexure based nano-positioning stage actuated by VCMs. This stage has a 4-DOFs about x, y, z, and θ_z, and its resolution is 50nm level. There is an additional coarse manual stage to roughly adjust the gap between the probe tip and target object. To collect the measurement data and control the nano-positioning stage in real time, we used a DSP based real-time controller (DS1103). A signal of variations of the vibrating probe related to the distance between the probe tip and measurement surface was observed.



(a)

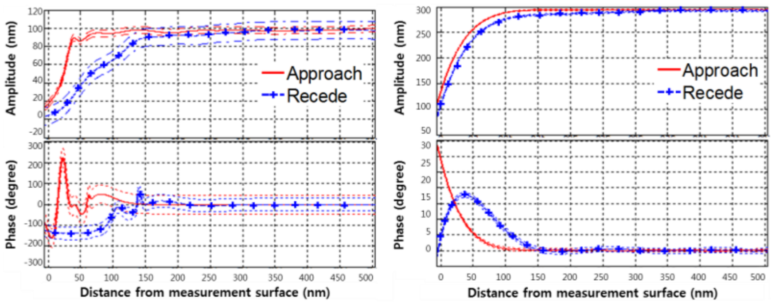


(b)

Figure 2 : (a) Picture of the experimental setup (b) Schematic of the experimental system setup

2.2 Results and discussion

For the duration of this experiment, the vibrating probe was oscillating at its natural frequency 947.8Hz and the amplitude was set to 100nm and 300nm, respectively. The reference of the phase of output signals was input drive signals. In figure 3(a), 100nm amplitude signals about approach and recede have different path because of the attractive interaction force. However, in figure 3(b), 300nm amplitude signals in approach and recede case are similar path due to counteracting the interaction force.



(a) (b)

Figure 3 : The variations of the amplitude and phase of the probe against distance from measurement surface when the initial vibration was (a) 100nm (b) 300nm

3. Conclusion

We designed a vibrating probe system having an easy change feature for multiple probes and observed variations of the amplitude and phase of a vibrating probe in resonance frequency as it approached to the measurement surface. The interaction force is related to the distance between the probe tip and the measurement surface and it was observed through variations of amplitude and phase of output signal. We also investigated the influence of the initial amplitude of the vibrating probe on the interaction force. We will study the effects of mechanical properties of the probe on the measurement performance with this system in the future.

Acknowledgment

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References:

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