A Novel Three-axis Vibrating Micro-CMM Probe with Isotropic Probing Forces

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Abstract

Over the past decade there have been a number of new designs and realisations of micro-CMM probes. However, there are still some issues with probe design that need addressing. For example, many probe designs have relatively high probing forces, or long over-travel distances potentially resulting in damage to the object being measured; surface forces can adversely affect the performance of probes that do not operate in an oscillatory mode; some probes do not operate in three axes and many do not operate with equal probing forces in each of their axes. The probe design presented in this paper addresses all of these issues. The new probe uses a triskelion flexure arrangement with in-built piezoelectric sensing and actuation to allow oscillatory behaviour that ensures that the probing direction is always normal to the surface of the object being measured. The design of the probe is presented along with the results from preliminary experiments to verify the design considerations.

1 Introduction

Developments in 3D micro-scale manufacturing rely on our ability to perform traceable, 3D verification of the resulting product dimensions. Modern micro-co-ordinate measuring machines (micro-CMMs) have been increasing in accuracy at a similar rate to modern manufacturing capabilities – some now having accuracies of 250 nm in relativly large measurment volumes [Leach 2009]. However, the accuracy of these micro-CMMs rely on similar developments in probe capabilities, which is now lagging. Current micro-CMM probes have reached the limit of their development and, without a shift in the technology used to produce them, accuracies will not be able to increase in step with manufacturing techniques. Various novel techniques are being developed to increase the accuracy of micro-CMM probes, a review of which can be found in [Weckenmann 2004].

2 The micro-CMM probe

Current research at NPL is focussed on the development of a micro-CMM probe that will address the main problems faced by micro-co-ordinate metrology [Claverley 2009]. A schematic diagram of the new NPL micro-probe is shown in figure 1 and its main features are discussed in the following sections.

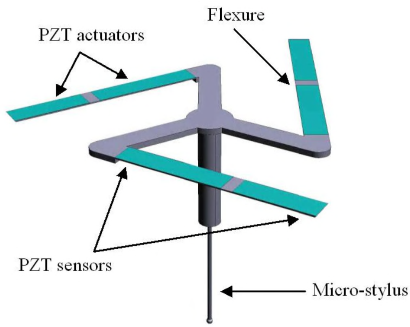

Fig. 1. A schematic diagram of the micro-CMM probe

2.1 Isotropy

The ability of the probe to exert equal probing forces in all axes is essential to allow fast scanning. Any newly designed probes should therefore exhibit isotropy and this was a primary requirement of the NPL micro-probe. The initial designs were developed using a finite element model of the mechanical structure of the probe [Stoyanov 2008].

2.2 Surface forces

Surface interaction forces, such as the capillary force or the electrostatic force, are usually not significant on the macro-scale, being overpowered by gravity or by the probing forces of large-scale CMMs. This is not the case for micro-scale co-ordinate metrology, which, if it aims to accurately measure high aspect ratio micro-structures, will be performing tactile probing with micro-styli whose tip diameters will be below 100 µm. Surface interaction forces become increasingly disruptive when using a micro-stylus with a tip diameter reduced below 200 µm [Bos 2007]. Interaction forces also become more disruptive when the distance between the stylus tip and the measurement surface is reduced below 1 µm. The interaction forces will also increase and may cause false triggering and damage to both the probe and the measurement surface. Adhesion to the measurement surface while retracting could also cause damage to the probe [Bos 2007]. Counteraction of these surface forces is essential if any micro-CMM probe is to be accurate while probing at the micro-scale to nanometre accuracy. Therefore, the NPL micro-CMM probe was designed such that it could vibrate. These vibrations are forced on the probe through six piezo-electric actuators (two on each leg) and can be controlled such that true 3D probing is possible.

2.3 Low probing forces

The vibrations of the probe will also act to reduce the effective probing force to zero. Surface contact by the NPL probe is not recorded as direct contact with the measurement artefact but as an interaction with the surface force field that extends from the surface. As the vibrating micro-CMM probe comes into the influence of the force field, the damping caused by these forces will alter the vibration characteristics of the probe, which will be detected by six piezo-electric sensors on the device, as shown in figure 1. The individual surface forces were investigated and modelled [Claverley 2010] and the minimum vibration amplitude required to counteract the surface forces was estimated from the model.

2.4 Production and assembly

The triskelion flexures are made using MEMS production techniques such as sol-gel spinning, deposition and lithography. A risk analysis study has been performed on the micro-probe design to define the elements critical to the funtion of the device [Sun 2009]. Various techniques are being investigated for the production of the stylus, which must be made of tungsten carbide. The working of the microbe depends on the ability to assemble the triskelion flexures with a micro stylus. Many assembly possibilities are being researched [Smale 2009].

3 Preliminary results

Experimental work has consisted of verifying the mechanical vibrations of the device. This work has helped verify the previously mentioned theoretical models (both FE and analytical).

4 Future work

Further vibration experiments using precision alignment stages will be used to verify the surface interaction model.

5 Acknkoledgements

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6 References

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