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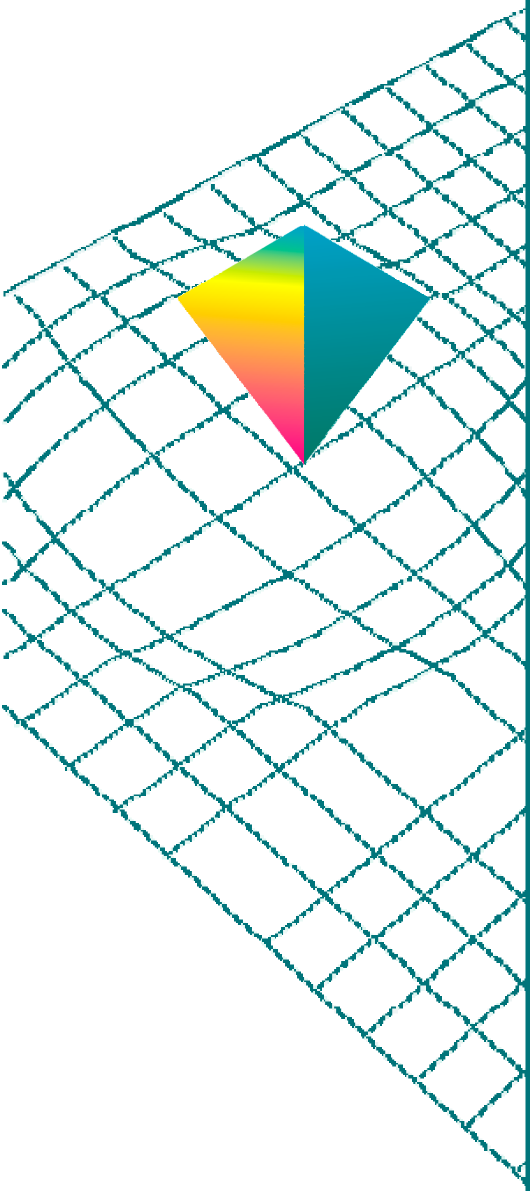

50. Internationales
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Maschinenbau von Makro bis Nano / Mechanical Engineering from Macro to Nano

Proceedings

Fakultät für Maschinenbau /
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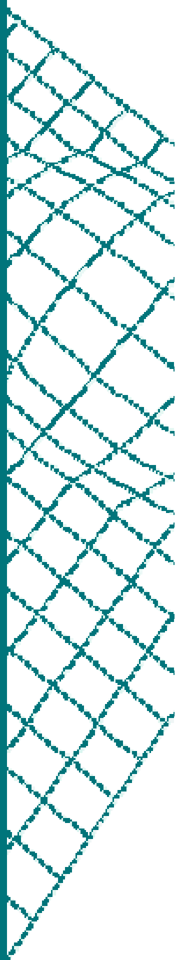

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50. Internationales Wissenschaftliches Kolloquium
Technische Universität Ilmenau
19.-23. September 2005

Dachao Li / Cuiyun Jin / Yalin Feng / Tong Guo/ Xiaodong Hu / Jinping Chen / Xing Fu / Xiaotang Hu

In-Plane Micro-motion Characterization for MEMS/NEMS Using Machine Vision with Nano-Resolution

ABSTRACT

A fully integrated optical and electrical measurement system made of off-the-shelf optical components and electrical instruments that characterizes in-plan micro-motions both in situ and nondestructive for MEMS/NEMS dynamic performance analysis at the wafer/die level automatically is presented. Two key techniques of blur image synthetic and stroboscopic dynamic imaging are implemented to characterize both periodic and non-periodic in-plane micro-motions based on machine vision technology. Both motion amplitude and resonate frequency could be measured through sweep frequency t and sweep voltage by these two techniques. Experimental results indicate that the methods have good measurement accuracy and speed, the measurement repeatability is about 40nm under 20X objective and the motion frequencies which could be measured is up to 2MHz in our system.

MEASUREMENT SYSTEM

The functional diagram of in-plan micro-motions measurement system based on the virtual instrument technology is shown in the Fig.1. To fulfill rapid characterization of MEMS/NEMS devices, the system is composed of: 1) a video camera (Redlake MegaPlus 1.6i) and a frame grabber (NI PCI-1422) for recording the behavior of devices in real-time, 2) an integrated computer control and data acquisition unit which are handled by a variety of standard internal plug-in cards (NI PCI-6070E) and external GPIB instruments (Tektronix AWG2005 arbitrary waveform generator) to supply driver signals, control voltages and to measure the MEMS/NEMS performance automatically, 3) Strobe control circuit developed by ourselves to supply pulsed illumination signal, 4)a micro probe station and an optical microscope system, and 5) a software analysis package that processes the captured images and signals, generates testing reports. The control and analysis software is developed by LabVIEW. With friendly user interface, open software architecture and significantly faster measurement methods, the system could be used practically for MEMS/NEMS research and development.

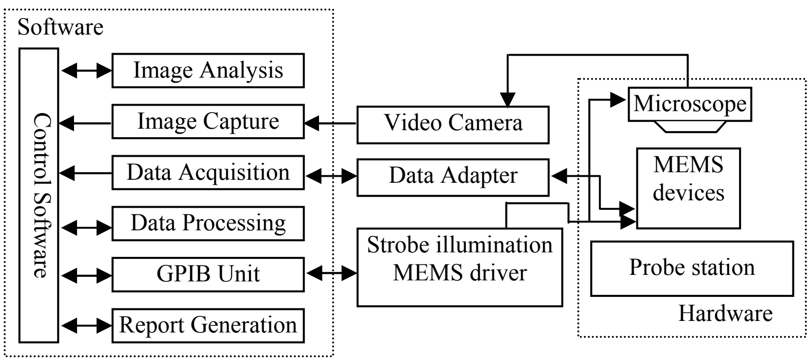

Fig.1. Diagram of in-plan micro-motions measurement system

MEASUREMENT TECHNIQUES AND EXPERIMENTAL RESULTS

Blur image synthetic is developed under the condition of continue lighting[1]. The in-plane micro motion's measurement of any visible MEMS structure, such as the displacement magnitude of a shuttle mass vibrating sinusoidally, is accomplished optically using two digital images captured from a simple video camera mounted on a microscope, a time-integrated blur image of the device in motion, and a stop image of the device at rest. This method could be carried out very easily for both periodic and non-periodic in-plane micro-motions with no frequency limits and the measurement speed is very quickly. However, it is impossible to characterize the motion phases during MEMS movement and the resolution is not very good. In a frequency sweep measurement for the MEMS resonator with this method, the basic parameters are set as follows. Start driving frequency is 20 KHz, the end driving frequency is 27 KHz and the sweep internal is 200Hz. The driving voltage is 160V and the offset voltage is 20V. And then the motion amplitudes of the MEMS resonator at different driving frequencies are obtained in Fig. 2.

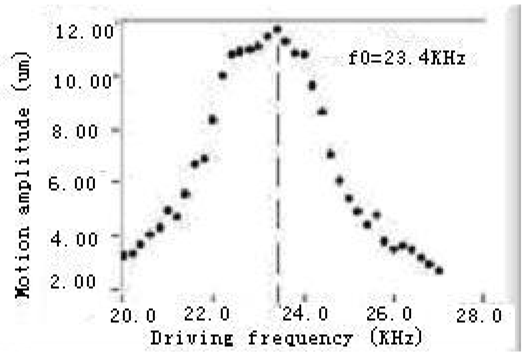

Fig.2. Amplitude frequency response of MEMS

Stroboscopic dynamic imaging is carried out then to fulfill the measurement of different motion phases and improve the measurement resolution greatly[2,3]. The principle is using strobe light to illuminate motion MEMS device with high speed and the strobe light is frozen at one motion phase when the motion frequency of MEMS equal to strobe frequency. At the motion phase the clear motion image of MEMS device is got through exposure several times using CCD. But this technique could only be used for periodic in-plane micro motions and the frequency up-limit is about 2MHz in our system. Novel motion detection algorithm based on phase correlation, block matching and sub-pixel location is put forward to analyze the motion image series. Estimating of MEMS in plane micro-motions is realized quickly and accurately by combining time domain and frequency domain measurement. The phase-amplitude response of MEMS resonator in one motion period at driving frequency of 22 KHz is shown in Fig. 3. Experimental results indicate the measurement repeatability is about 40nm under 20X objective with this method in our system.

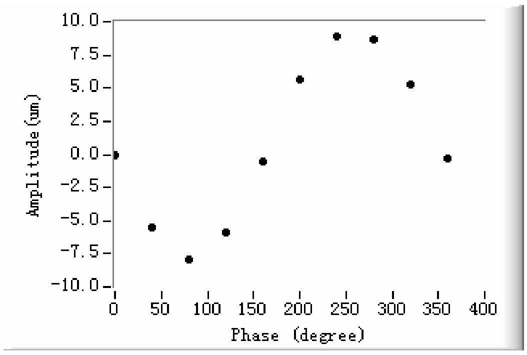

Fig.3. Phase-amplitude response of MEMS resonator

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