PERFORMANCE OF A VIBRATION-DESENSITIZED SCANNING WHITE LIGHT INTERFEROMETER

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ABSTRACT
Scanning white light interferometers (SWLI) normally require vibration isolation for optimum performance; frequently they are located in "metrology labs" far removed from the shop floor. A new commercial "vibration tolerant" scanning white light interferometer suggests that precision surface measurements might be made much closer to the shop floor. This paper examines what is meant by "vibration tolerant" and describes a method for evaluating the performance of similar instruments.

INTRODUCTION
To enable surface quality measurements in manufacturing environments, optical profilometry may not be the first traditional choice due to measurement sensitivity to instrument vibrations. To address this sensitivity a commercial scanning white light interferometer (or SWLI) has been introduced that promotes increased vibration tolerance (the Zygo ZeGage). In this work, the SWLI's mechanical response to forced vibration was evaluated using a frequency sweep technique. Replicated nickel surface roughness standards were measured while the SWLI platform was subjected to forced vibration from a modal shaker. Surface topography responses to vibration frequency and amplitude were found to correspond with the mechanical resonances of the instrument structure. Additionally, the influence of environmental disturbance due to an operating machine tool was evaluated. The degradation of the measurement result for optical-quality surfaces was detectable at lower vibration amplitudes than for conventionally-machined (rougher) surfaces. However, the nature of the measurement result degradation was similar.

PERFORMANCE EVALUATION
In previous work, reference surface topographies measured by the SWLI in a manufacturing environment and with a stylus profilometer in a metrology lab were found to agree within the slope range of the SWLI [1]. Mechanical frequency response functions for the SWLI were determined and surface topography response to forced vibration was investigated.

Response to Milling Machine Vibration
The SWLI was placed on a table in close proximity to a horizontal milling machine during machining. Measurements of etched silicon and machined aluminum surfaces were performed. The amount of data loss was found to vary inversely with magnification. Conventionally machined surfaces exhibited less data loss than optical-grade surfaces.

Instrument Structural Evaluation
The SWLI was placed on a rolling hydraulic lift cart which provides some vibration isolation from the operating environment. A modal shaker was mounted to the cart base to provide an input force and low-mass accelerometers were used to measure the corresponding vibration. Direct and cross frequency response functions were measured from the shaker to the cart top (where the SWLI was mounted), the SWLI sample table, and the SWLI optical column, in response to nominally vertical and horizontal forced vibrations at the cart base. Example results for the response of the optical column to nominally vertical cart base input are displayed in Figure 1.

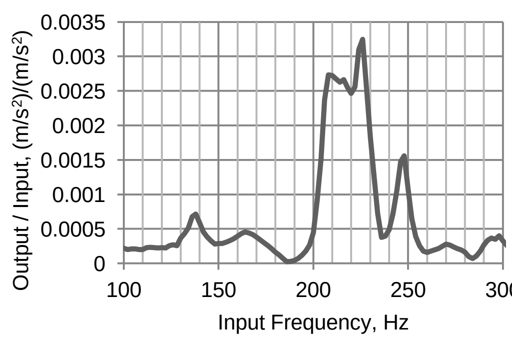

FIGURE 1. Vertical response of SWLI optical column to vertical modal shaker input.

Response to Forced Vibration

Using the modal shaker mounted on the cart base, a sinusoidal vibration with constant 500 nm amplitude at the cart top was applied. Deviation in the measured areal arithmetic average roughness, Sa, over the frequency range is shown in Figure 2. These Sa variations appear to correspond to the frequency response characteristics of the SWLI optical column.

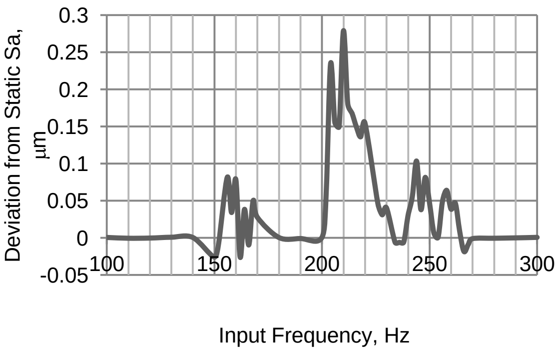

Figure 2: Sa deviation from static, 0.04µm Sa reference surface with 50x Mirau objective.

For frequencies near a mechanical resonance, the surface topography shows peaks and valleys parallel to the interference fringes, occurring at twice the fringe frequency. Figures 3 and 4 illustrate fringes and surface topography with forced vibration near a mechanical resonance. Slight data loss is visible in some of the surface "valleys" at regions of high local slope. Similar phenomena were exhibited by rougher reference samples. Using the modal shaker to force constant-amplitude vibrations to the instrument as a whole, as well as constant amplitude vibration of the optical column and sample table, amplitude and spatial parameters of surfaces were investigated.

SUMMARY

Through modal testing, mechanical resonances in the SWLI instrument were located. Forced vibration of the SWLI indicated maximum deviation from static surface roughness measurements near resonances, exhibiting a surface topography with peaks and valleys at twice the interference fringe frequency. This effect was found to be less obvious with surfaces of increasing roughness. By forcing constant amplitude vibration to different components of the instrument, the effect of vibration at each location on surface measurement was investigated. Classification schemes beyond Sa were applied to the resulting measurements.

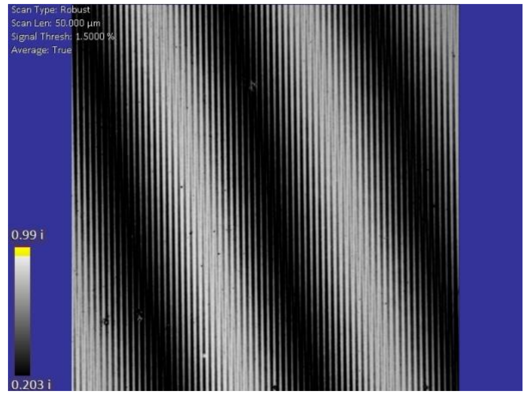

Figure 3: Interference fringes at static condition.

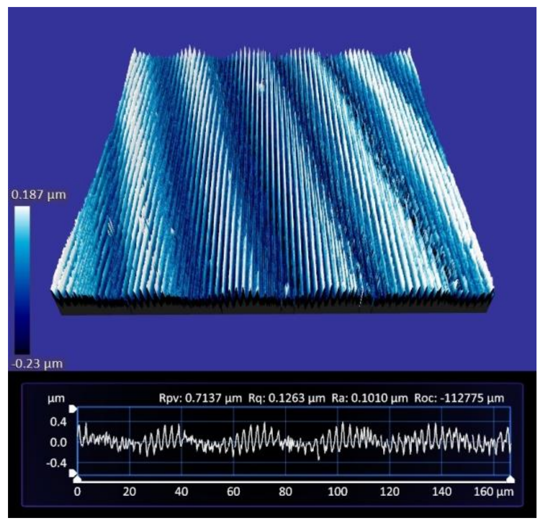

Figure 4: Indicated surface topography at 210 Hz, 500 nm vibration amplitude at cart top.

REFERENCES

[1] Badami V, Liesener J, Evans C, de Groot P. Evaluation of the measurement performance of a coherence scanning microscope using roughness specimens. Proceedings of ASPE Annual Meeting. Denver, 2011.