PRIMARY CALIBRATION OF ACCELEROMETERS BY LASER INTERFEROMETRY AT THE NATIONAL RESEARCH COUNCIL

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Abstract

This paper describes the absolute accelerometer calibration system developed at the Institute for National Measurement Standards, NRC. Details of the calibration procedure and the associated equipment are described. The system, based on laser interferometry, operates from 20 Hz to 5000 Hz, with an estimated uncertainty of less than 0.5% at a confidence level of 95%.

Introduction

Advances in the design of structures and machines over recent years have created stringent demands for investigation into vibration problems. Accurate measurements of vibration have become important with more research efforts devoted to the design of better transducers. As a result, accurate calibrations of accelerometers are necessary to verify design parameters and performance characteristics.

Calibration Arrangement

A standard absolute accelerometer calibration procedure [1] and the principles of operation [2, 3] have been described. The measurement set-up is shown in Figure 1. It consists of a Michelson interferometer with associated equipment as shown. For frequencies up to 800 Hz the number of fringes R_f per vibration period is counted. It can be shown that the displacement amplitude D of the vibration is given by

$$D = R_f \frac{\lambda}{8}$$

where λ is the wavelength of the laser. For a sinusoidal vibration at frequency f, the acceleration amplitude A is given by

$$A = 4\pi^2 f^2 R_f \frac{\lambda}{8}$$

For frequency ranges from 800 Hz to 5000 Hz the output signal of the detector is filtered with a bandbass filter. According to the standard procedure [1], the filtered signal has a number of minimum points at various accelerometer displacements. For a helium-neon laser with a wavelength of 0.6328 μm, the acceleration, in ms^{-2}, is given by

$$A = 39.478 \times 10^{-6} d f^2$$

where d is the displacement amplitude in micrometres, and f is the frequency of the shaker in hertz.

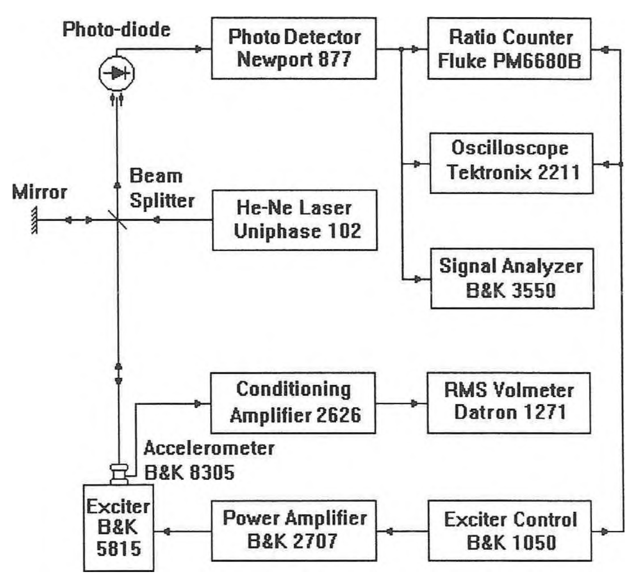


Figure 1 *Accelerometer calibration set-up*

Implementation Considerations

External vibrational noise is one of the most serious problems encountered in measuring small displacements. In the arrangement used at INMS, the entire system is mounted on a heavy 5 cm thick steel bench supported by a 10 cm thick granite table that is resting on air-pads (Micro-g air table, Technical Manufacturing Co.). The interferometer is mounted on top of the shaker supported by four box-shaped columns, and isolated by a second air-pad system, as shown in Figure 2. Other disturbances, such as airborne noise may be reduced by performing the calibrations in the evening or overnight.

Thermal air currents generated by the cooling fans of the equipment can cause random fluctuations in the refractive index of air. This leads to random changes in beam intensities. The effect can be effectively eliminated by shielding the beam path.

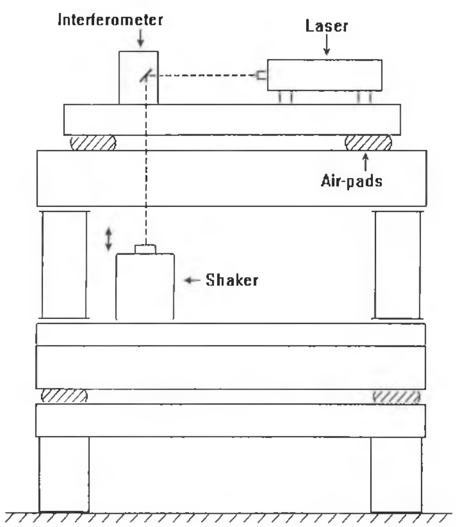


Figure 2 *Accelerometer calibration*

Uncertainties

The calculation of the absolute uncertainty for the calibration is governed by international standard [1]. The uncertainty audit of the absolute calibration at a frequency 160 Hz is listed in Table 1. The uncertainties of the frequency ratio counter, charge amplifier and voltmeter are estimated based on manufacturers' specifications. The estimated uncertainties due to tilting (orthogonality), transverse vibration and waveform distortion are determined experimentally. The overall uncertainty calculated according to Annex A in [1] is less than 0.5% at 95% confidence level.

Table 1 *Uncertainty contributions for a B & K type 8305 standard reference transducer calibrated at a frequency 160 Hz with an acceleration 10 ms^{-2}*

Error source	Uncertainty
Voltmeter & charge amp.	±0.08%
Frequency counter × 2	±0.002%
Ratio counter	±0.2%
Distortion	±0.5%
Tilting	±0.1%
Transverse vibration	±0.06%
Temperature	±0.1%
Estimated standard deviation (3 measurements)	±0.04%

Conclusions

The absolute accelerometer calibration system developed at INMS has an uncertainty of less than 0.5% at 95% confidence level. Future investigation related to orthogonal movements of the shaker-head may reduce the uncertainty.

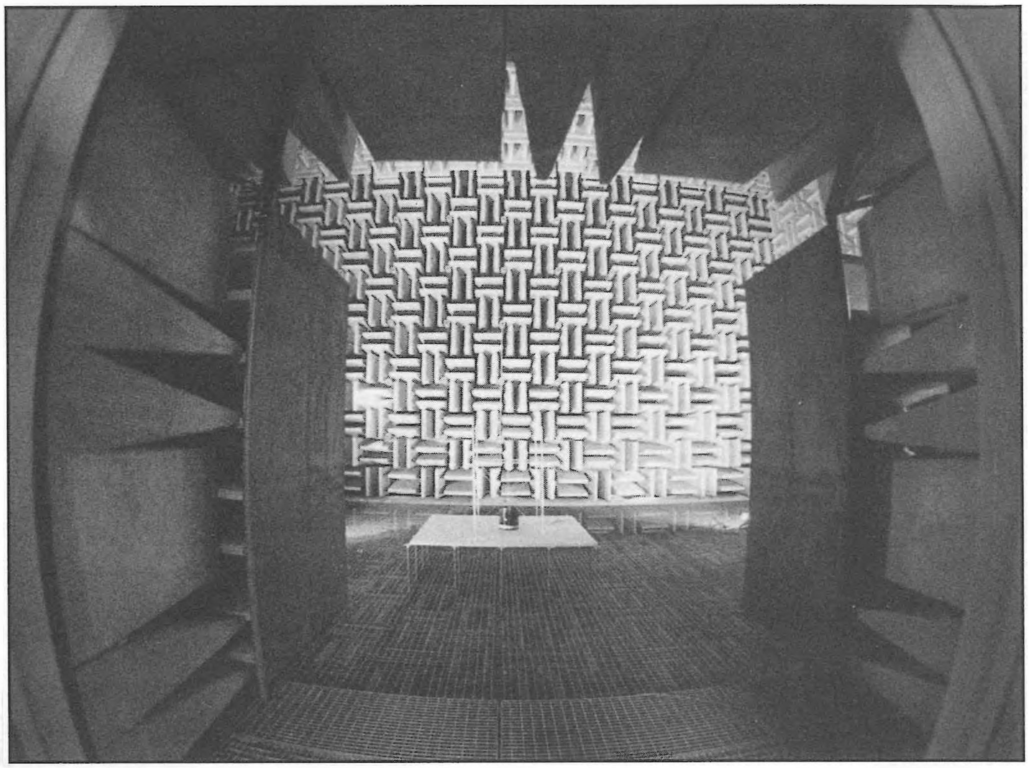
References

[1] *ISO 5347 -1*, 1993: "Methods of calibration of vibration and shock pick-ups"

[2] H. A. Deferrari, R. A. Darby and F. A. Andrews, "Vibrational displacement and mode-shape measurement by a laser interferometer," *J. Acoust. Sco. Am.*, Vol. 42, pp. 982-990, 1967.

[3] S. M. van Netten, "Laser interferometer microscope for the measurement of nanometer vibrational displacements of a light-scattering microscopic object", *J. Acoust. Sco. Am.*, Vol. 83, pp. 1667-1674, 1988.

[4] J. T. Verdeyen, *Laser Electronics*, Englewood Cliffs: Prentice-Hall, 1981.



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