TESTING OF THE LASER INTERFEROMETER OF
AN ACCELEROMETER CALIBRATION WORKSTATION
BY MEANS OF GAUGE BLOCK

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Abstract: A method for calibration of the laser interferometer of an accelerometer calibration workstation by means of gauge block is proposed.

Keywords: vibration, laser interferometer, gauge block.

1. INTRODUCTION

State Enterprise Ukrmetrteststandard continues to create the primary national standard of vibration parameters.

This national reference is now being created on the basis of the 9155D Accelerometer Calibration Workstation with the 9155D-575 Laser Interferometer Primary Option (hereinafter - 9155D Workstation) manufactured by Modal Shop Inc., USA. The 9155D Workstation meets the recommendations specified in ISO 16063:11 [1]. 9155D Specifications are as follows:

- frequency range – 5 Hz – 20 kHz
- acceleration magnitude range – 0,1 – 300 m/s^2
- expanded measurement uncertainties (k=2, P=0,95) are represented in Table 1.

Table 1. Expanded uncertainties

F, Hz	Uj, %	Phase, $U\varphi j$, °
5	1	2
5,1 - 99	0,7	1,5
100 - 1000	0,5	1,5
1001 - 5000	0,7	1,5
5001 - 10000	1,5	1,5
10001 - 15000	3	1,5
15001 - 20000	5	2

It is possible to brake down the components of uncertainty into three groups:

1) components of uncertainty related to the measurement and conversion of electrical quantities at the output of the vibration transducer;

2) components of uncertainty related to the measurement of vibro displacement (linear displacement) by means of a laser interferometer;

3) components of uncertainty related to the mechanical and magnetic properties of the shaker, the massive inertial platform and the accelerometer.

As regards the second group of uncertainty components.

This group includes the components in compliance with the recommendations of ISO 16063-11 and the components presented in the manufacturer's technical documentation. The numerical values of the standard uncertainties are provided by the manufacturer.

The components are as follows (for the frequency range interval from 100 Hz to 1000 Hz):

- $u(\varphi_{M,Q})$ - effect of interferometer quadrature output signal disturbance on phase amplitude measurements, $u(\varphi_{M,Q}) = 0,023$ %;

- $u(\varphi_{M,F})$ - interferometer signal filtering effect on phase amplitude measurement (frequency band limitation); $u(\varphi_{M,F}) = 0$ %;

- $u(\varphi_{M,VD})$ - effect of voltage disturbance on phase amplitude measurements (e.g. random noise in photoelectric measuring chains), $u(\varphi_{M,VD}) = 0$ %;

- $u(\varphi_{M,PD})$ - effect of phase disturbance on phase amplitude measurement, $u(\varphi_{M,PD}) = 0$ %;

- $u(\varphi_{M,RE})$ - residual interferometric effects on phase amplitude measurements, $u(\varphi_{M,RE}) = 0,017$ %;

- $u(\lambda)$ - laser frequency stability, $u(\lambda) = 0$ %.

Calibration of the laser interferometer in practice is measurement of the wavelength of the laser of the interferometer.

This method has its own significant deficiencies:

- measuring of the wavelength of a laser is an indirect method, not an absolute method;

- the correctness of the optical scheme is not checked;

- the accuracy of analog-to-digital and digital-to-analog converters in a laser interferometer are not verified;

- it is not always possible to measure the wavelength of a laser in a laboratory of vibration measurements. As a rule, this requires dismantling of the laser head and its delivery to the appropriate

optical laboratory. This is inconvenient and, in case of a distant optical laboratory – undesirable;

A method for calibration of interferometer by means of a length gauge block is proposed. This method allows to evaluate the components of standard uncertainty in the measurement of vibro displacement by means of a laser interferometer.

It should be noted that the existing scientific literature [2], [3] mainly suggests the gauge block calibration methods with the use of a laser interferometer. Thus used laser interferometers are designed for traditional length measurements. Multiple presently existing types of laser interferometers perform various kinds and have different functionalities and different measurement accuracy. Therefore, it is impossible to draw any conclusions concerning all laser interferometers.

The purpose of this article is to demonstrate that for laser interferometers used in vibration, the reverse task of testing the interferometer by means of a gauge block is reasonable and, in some cases, preferable.

2. METHOD FOR LASER INTERFEROMETER CALIBRATION DESCRIPTION

The experiments featured the gauge block made by Mitutoyo, Japan, with the nominal value of 5 mm. This gauge block is shown in Figure 1
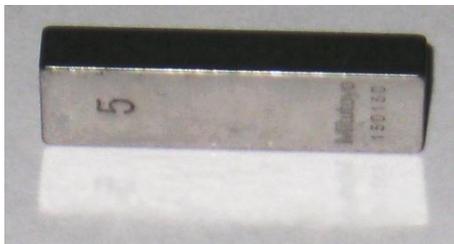

Figure 1. Gauge block

The standard uncertainty of length value for this gauge block is 30 nm, or, in relative units, 0,0006 %.

The combined standard measurement uncertainty of the components related to the laser interferometer should be calculated from formula (1)

$$u(L) = \sqrt{u^2(\varphi_{M,Q}) + u^2(\varphi_{M,F}) + u^2(\varphi_{M,VD}) + u^2(\varphi_{M,PD}) + u^2(\varphi_{M,RE}) + u^2(\lambda)}$$

(1)

When inserting the numerical values $u(L)$ equals 0,03 %.

Therefore, the accuracy of the gauge block is fifty times (!) higher than that of the laser interferometer in accordance with the manufacturer's specification.

Note 1. The main part of the uncertainty of the laser interferometer corresponds to measurements of displacement within the laser wavelength (less than 632 nm). Nevertheless ratio of uncertainties is significant.

Note 2. During operation of the standard 9155D program the signal from the laser interferometer is input to the data acquisition unit as follows:

- at frequencies up to 1 kHz - from the digital output to digital input;
- at frequencies above 1 kHz - from the analog output of the laser interferometer to the analog input of the data acquisition unit.

When an additional program is used to measure the gauge block length the signal from the analog output of the laser interferometer is input to the analog input of the data acquisition unit. This means that while testing a laser interferometer with a gauge block it becomes possible to evaluate the uncertainty of the result of measurements with account of all transformations of the signal, including digital-to-analog and analog-to-digital conversions of sine and cosine signals.

Implementation of this idea necessitated a solution for measurement of the length of gauge block by means of a laser interferometer. To accomplish this it was necessary to ensure movement of the reflecting mirror to the exact length of the gauge block. The laser beam should be continuously reflected from the mirror and never lost.

The mirror should move smoothly and be perpendicular to the laser beam. The signal reflected from the moving mirror should continuously enter the photodetectors of the interferometer, and the speed of movement should be below the maximum allowable for this particular interferometer (less than 0.5 m/s).

This was accomplished by means of a measuring microscope with a movable platform. This microscope is designed for length measurements with use of gauge blocks. The microscope may be adjusted for setting the gauge block. The platform of the microscope is equipped with a spring that always returns it to the initial position at low speed (Figure 2).

1 -Laser head; 2 – laser beam; 3 – mirror; 4 – movable platform; 5 – gauge block

Figure 2

The standard program that comes with the 9155D workstation does not provide linear displacement measurements. Mr. Mark Schiefer from Modal Shop Inc., the general developer of the 9155D, developed and kindly provided the necessary software.

This program is written in the LabVIEW platform for the National Instruments acquisition modules that are used in the 9155D workstation. This program enables linear displacement measurements. Figure 3 explains the measurement process.
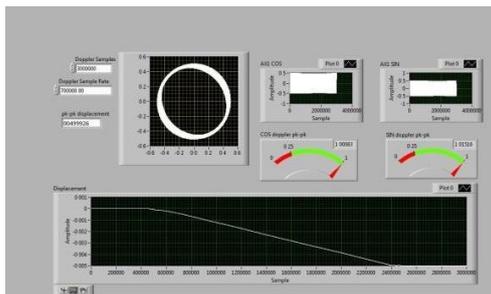

Figure 3. Measuring process

The results obtained with multiple measurements are as follows:

- the standard uncertainty related to the systematic bias in the measurement of linear displacement - u_B is 0,4 μm at a distance of 5 mm, which corresponds to 0,008 % as to the length of the gauge block.

- the Type A uncertainty corresponds to the systematic bias u_A equals 0,2 μm, or 0,004 %.

3. CONCLUSIONS

The results of the described experiments lead to the following conclusions:

- calibration of laser interferometers by means of a gauge block is possible;

- this method of calibration is a direct (absolute) method because it uses a material measure of length, which is always preferable over indirect measurements, such as measuring of the laser wavelength;

- calibration by this method is much easier than periodic measurement of the laser wavelength;

- the uncertainty of this method of calibration is justified in terms of the accuracy of measurements and allows to confirm the uncertainty of measurements of the laser interferometer as declared by the manufacturer.

4. REFERENCES

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