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Investigation of vibrations acting on the mechatronical comparator

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Abstract:
Oscillations of the comparator, which is used for the dynamic calibration of long optical line scales, are analyzed in the paper. The accuracy of determination of the position of optical lines on the scale depends on the velocity of the carriage, which transports the microscope with a CCD camera in relation to the line scale. Oscillations influence the velocity equability, its value, and at the same time the error of the comparator. The base part of the comparator is acted upon by external excitations which come through the foundation and supports, also due to natural frequencies of the comparator set. It is shown in the work that vibration surroundings acting on the comparator have a random character and correspond to the criteria of the normal (Gauss) distribution. It is proved experimentally that preaching amplitudes of measured components of vertical and horizontal oscillations influence the stability of the carriage movement which causes the measurement error.
Key words: Mechatronical comparator, vibration, dynamic calibration, measuring, research.

Introduction

The world practice witnesses increased focusing on the improvement of line gauge technologies and application thereof in length measurement and precise controlled motion systems. Modern precision scale production technologies enable to create small-step displacement transducers with measuring possibilities that come close to those of optical interferometers. Currently, line gauges with 0.125 nm (1.25 Å) resolution are used in precision devices. A rapid advance of technologies, primarily micro- and nanotechnologies as well as microelectromechanic system (MEMS) technologies raises higher and higher precision requirements, measuring speed requirements and other requirements thus stimulating development of new precision length calibration systems [1] – [5].

Line gauges are calibrated by means of optical interference comparators with a sliding microscope for scale line viewing and with a sliding measurement scale. Interferometric measuring systems are used for precise measurement of the displacement of these sliding parts. Generally, the sources of the interferometer stabilized frequency radiation are double-frequency He-Ne lasers.

Besides many device characteristics whereon scanning of line gauges of the comparator is dependent, external factors affect the precision of the device as well. One of the utmost effects is produced by vibrations. Lengthwise vibrations affect the carriage speed dynamics which directly affects the scanning precision.

The length of the calibrated end gauge and the position of line centers are precisely determined (calculated) by processing of the measurement data, by estimating the corrections of the environment conditions on the basis of pressure, humidity, temperature and CO_2 content measurement results. The lengths of the scale intervals obtained from the measuring system are recalculated for the 20 °C temperature.

The impact of vibrations on the precision of calibration of line gauges is discussed in this paper.

Most dangerous are the vibrations that occur in the direction of the carriage motion (x axis) and torsional vibrations that occur on the carriage axis z (on x, y plane) which is perpendicular to the direction of motion x. Vibrations that occur in the direction of the length of the carriage, i.e. the carriage velocity and its dynamics determine the precision of scanning of the line gauge position. Precision is defined by means of a photoelectric microscope with a CCD camera.

Object of research

An interference comparator with air refraction coefficient compensation meets the technical and economic criteria by estimating the refraction coefficient from Edlen formula according to the results of measurement of the environment parameters or by means of a refractometer. The structural diagram of the equipment is shown in Fig. 1. It is based on a line gauge calibration comparator with a sliding microscope (10).

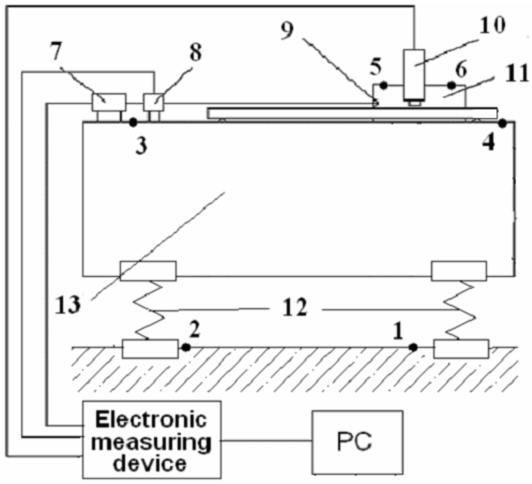


Fig.1. **A structural diagram of the comparator and vibration measuring points**

The comparator's frame (13) is made from granite and is mounted on vibration-proof supports (12), the microscope holder moves on air guides. The carriage (11) is driven by means of motor, worm reduction gear and friction gear. T, P and H are temperature, pressure and humidity meters, respectively. The laser measuring system comprises laser (7), interferometer (8) and retroreflector (9). Numbers 1 to 6 show the measurement points.

The position of line centers of the calibrated gauge is precisely determined (calculated) by processing the measurement data and estimating corrections for geometrical, instrumental and environmental errors.

The comparator is installed in a standard room.

The whole operation of the comparator and error compensation are computer-controlled.

Experimental tests

Experimental tests were conducted in measurement set-up shown in Fig. 1. The vibration measuring devices of the Denmark firm "Brüel & Kjær", with accelerometer 8306, vibrometer 2511, band-pass filter 1617, signal input and control board "Ebiol–Comlab–SeiTech" and personal computer IBM–50 were used for measuring of vibration parameters.

It was determinate during experimental investigation that dominated amplitudes of vertical and horizontal oscillations are comparatively of low frequencies (1-50Hz).

The results at points 3 and 4 are shown in Fig. 2, 3, 4.

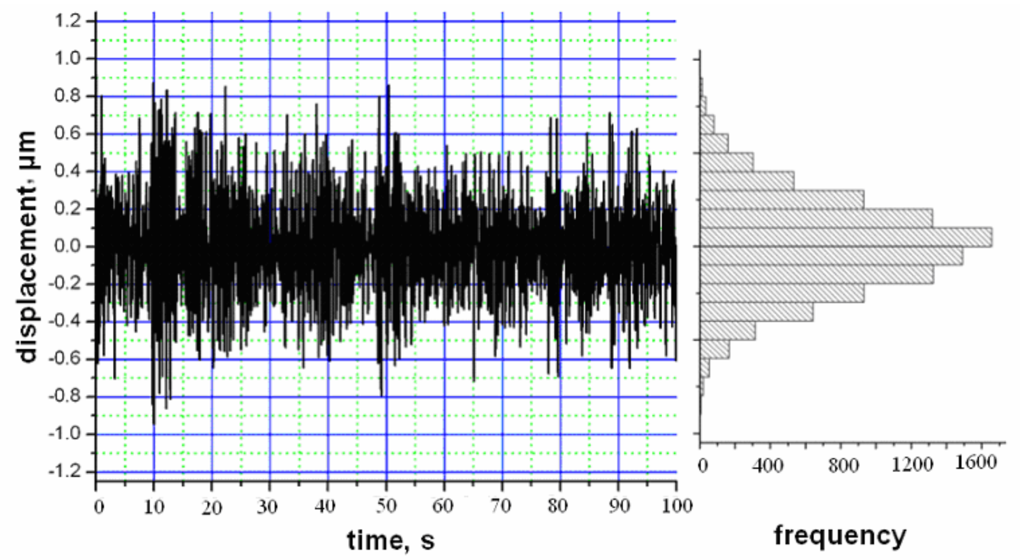


Fig. 2. **Typical the signal of the displacement and its histogram**.

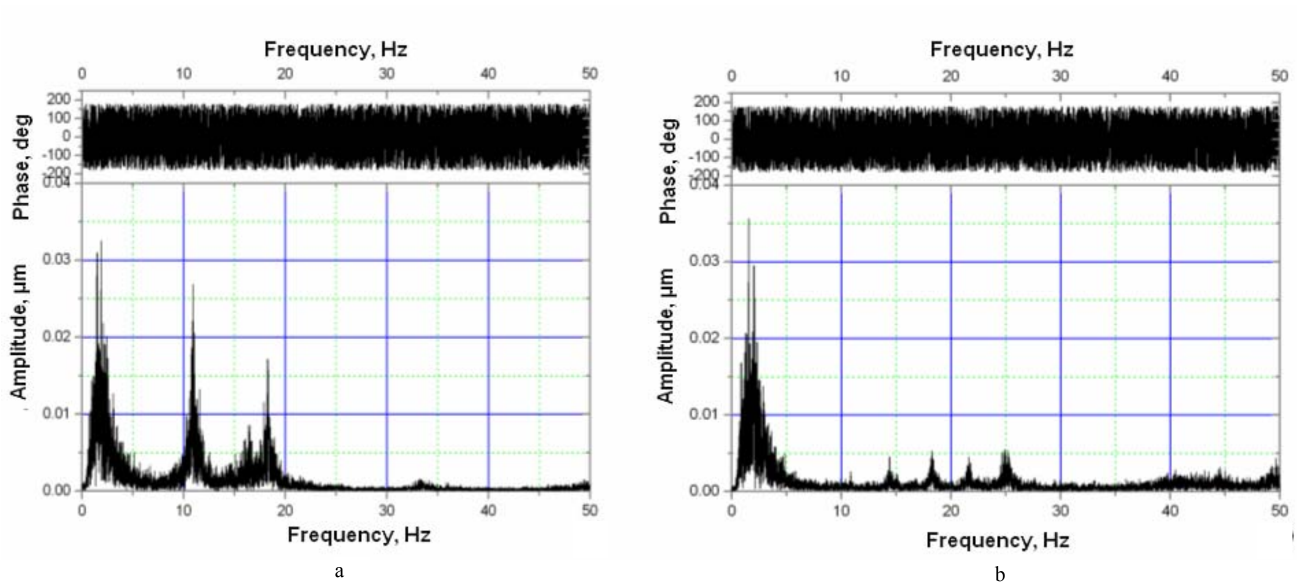
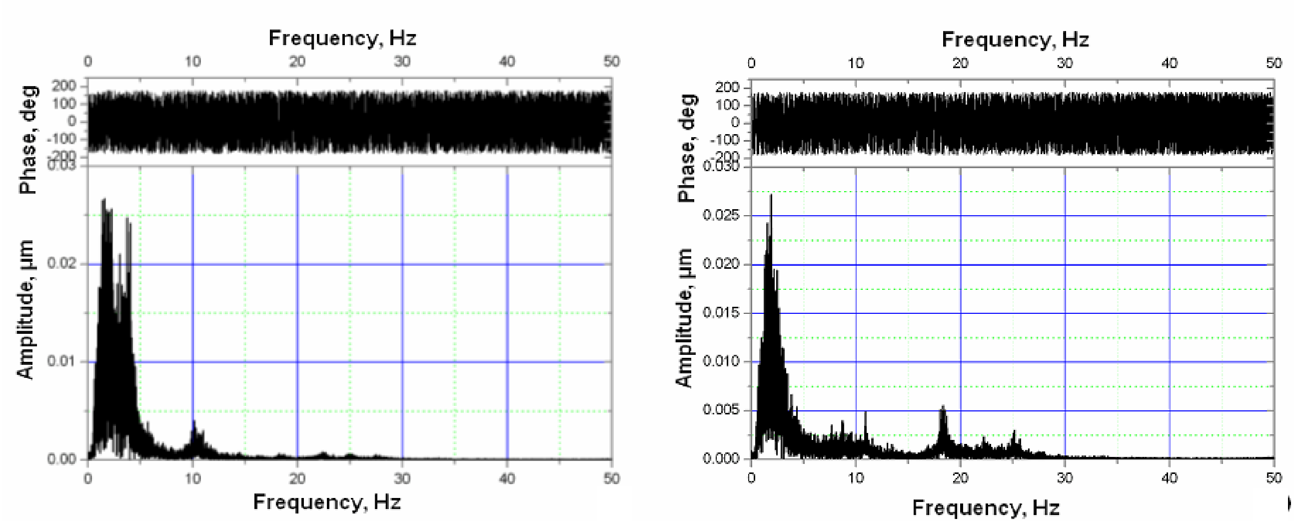


Fig. 3. **The spectrum of the displacement signal at the point 3: a - horizontal direction, b - vertical direction**



a b

Fig. 4. **The spectrum of the displacement signal azt thepoint 4: a - horizontal direction, b - vertical direction**.

Conclusions

1. It has been found that low-frequency vibrations are capable of affecting the accuracy of reading while the carriage with a microscope are moving.
2. The spectral amplitude values of the measured vibrations fluctuate from 0.026 to 0.036 µm.
3. The preventive means of reducing vibrations should be designed.

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Mechatroninį komparatorių veikiančių vibracijų tyrimas

Reziumė

Nagrinėjama virpesių įtaka ilgio matavimo komparatoriui, kuris skirtas ilgoms optinėms skalėms kalibruoti. Virpesiai matuoti taškuose ant komparatoriaus pagrindo. Gautas tipinis poslinkio signalas ir jo histograma. Atlikta spektrinė signalo analizė. Pateiktos išvados.

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