AUTOMATIC CALIBRATION OF GAUGE BLOCKS MEASURED BY OPTICAL INTERFEROMETRY

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Abstract. Construction and principle of operation of automatic interferometer for measurements of gauge blocks were described. The possibilities of the system based on phase shifting method and the software elaborated in Length and Angle Division of Central Office of Measures and Optical Engineering Division – Department of Precision Mechanics of Warsaw University of Technology were presented.

Key words: gauge block, Köster interferometer, exact fractions method, phase shifting interferometry

1. Introduction

The laboratory in Length and Angle Division of Central Office of Measures gets lately more and more gauge blocks, which are measured by optical interferometry. Increase a number of gauge blocks with tolerance grade K and 00, which are calibrated in Length and Angle Division caused modification typical Köster interferometer (KI) by introducing laser light source and phase shifting element.
The main advantages modification of Köster interferometer (KI) are:

- higher light level and stability of frequency (laser light source is using instead the discharge lamp),
- easier and shorter procedure calculation of length deviation of gauge blocks,
- the possibilities of flatness and parallelism gauge blocks determination from interferograms,
- the possibilities of storing interferograms in data base.

2. Measurements with modified Köster interferometer (KI)

Determination of the length deviation is based on the exact fractions method. The modified measurement system is shown below.

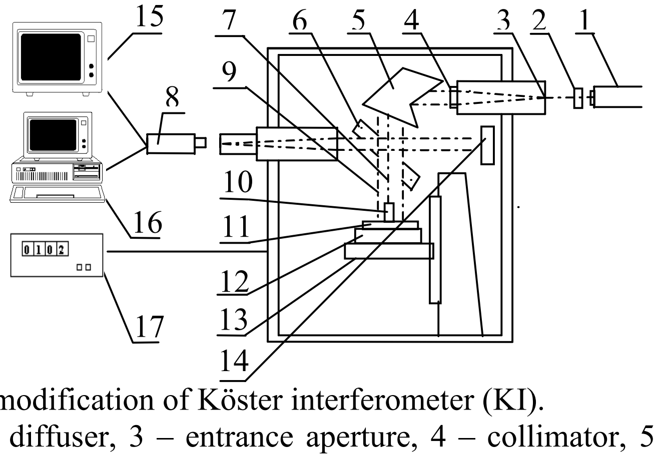

Fig. 1. The scheme of modification of Köster interferometer (KI).
1 – laser, 2 – rotating diffuser, 3 – entrance aperture, 4 – collimator, 5 – prism, 6 – beam splitter, 7 – measuring beam, 8 – CCD camera, 9 – reference beam, 10 - gauge block,

11 – reference plate,12 – piezo – ceramic phase shifter, 13 – table, 14 – reference mirror, 15 – video monitor, 16 - computer, 17 – power supply.
Single stabilised He – Ne laser is used as a light source, piezo - ceramic phase shifter is integrated with the interferometer base.

The length *L* of gauge block is defined as:

$$L = (m + u)\frac{\lambda}{2} \tag{1}$$

where: *m* – interference order, *u* – fringe fraction, λ - laser wavelength.
Interference order *m* is equal maximum whole number from fraction $\frac{L_{nom}}{\lambda/2}$, where L_{nom} corresponds to the nominal length of gauge block. The reading of fringe fraction *u* is taken from interferograms. The way of calculation of the fringe fraction *u* is shown in fig. 2.

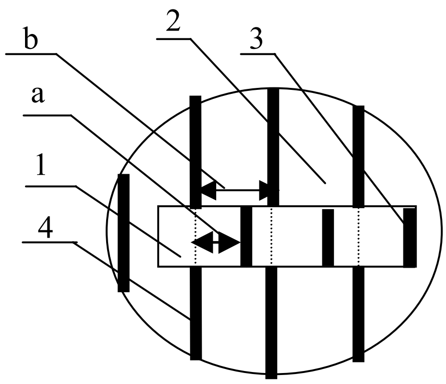

Fig. 2. 1 – gauge block, 2 – reference plate, 3 – fringe on the surface of gauge block , 4 – fringe on the surface of reference plate, a –length, which corresponds to the fringe fraction *u*, b – length between two fringes on the reference plate.
.Fringe fraction *u* is calculated from equation: $u = a/b$. Fringes are straight lines on fig. 2, but they are almost always curve in real situation (fig. 3).

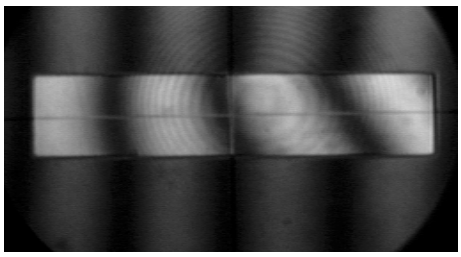

Fig. 3. The real interferogram.
Fig. 3 shows the interferogram of gauge block, which has significant deviation in flatness (it means that fringes on the surface of gauge block are curves) and significant deviation in parallelism (it means that segments between two fringes on the surface of gauge block and reference plate have various length). It is difficult to evaluate fringe fraction in this case in typical (KI), but in modified (KI) the value of fringe fraction can be exact obtained, when

fringes are curve lines [1]. In modified (KI) interferograms are observed by CCD camera, converted into digital form and stored in computer memory.

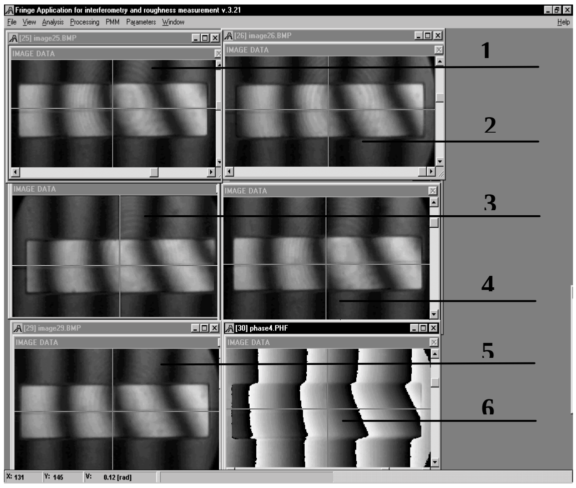

Fig. 4.

Five phase – shifted interferograms number 1÷5 (fig. 4) are captured and analysed in exact fractions method. Fringe fraction *u* can be evaluated from resulting phase image number 6 (fig. 4), which is similar to fig.2.

After estimate this value internal computer programme in Length and Angle Division enables procedure for evaluating the length deviation of gauge blocks. Length deviation depends on:

- temperature of gauge block,
- refractive index of air, which alters the pressure, temperature and humidity according to the modified Edlen equation [2], [3],
- the phase – change correction, which is attributed to reflection effects,
- fringe fraction *u*,
- vacuum wavelength,
- source size and the lens focal length.

The flatness and parallelism of gauge blocks are automatically determined from measurement system, which was described early (fig. 1), but there is various way of analysis. All the noises can be eliminated from five phase – shifted interferograms. It is possible to evaluate parameters P – V (peak–to-valley) and RMS (which describes experimental standard deviation from reference plate). The possibilities of modified (KI) are shown in fig. 5 and 6.

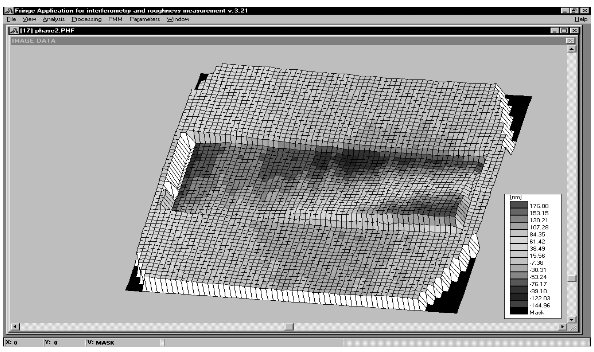

Fig. 5. Three – dimensional map the surface of gauge block and reference plate.

It possible to notice visible slope on the surface of gauge block, which describes deviation of parallelism gauge blocks. This value is given on the right side fig. 5 in the legend.

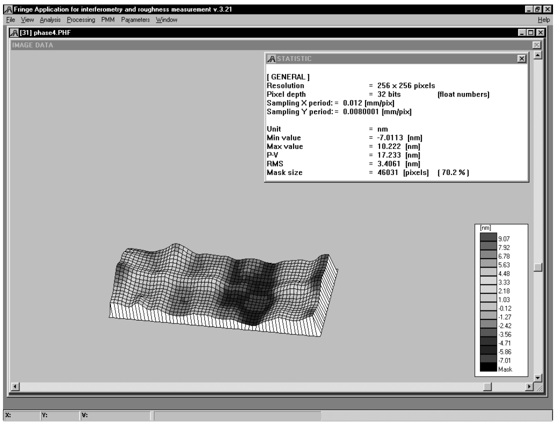

Fig. 6. Three – dimensional map the surface of gauge block.

Flatness deviation can be expressed by the peak-to valley P – V and RMS parameters or in the legend on the right side fig. 6. Fig. 5 and 6 correspond to images from fig. 3 and 4.

3. The uncertainty evaluation

In Length and Angle Division was elaborated one programme, which is used to the calculation of length deviation of gauge blocks and the second one, which is used to the uncertainty evaluation [4]. This programme enables the uncertainty calculation, which alters the thermal dilatation coefficient of gauge blocks, sort of material of gauge block, wavelength, stability of frequency light source.

4. Conclusions

Modified (KI) enables automatic acquisition and analysis of interferograms. Fringe fraction can be evaluated very quickly. The result of gauge block length deviation is determined with most higher accuracy than in typical interferometer. System is used to measure the flatness, parallelism of gauge blocks and tolerance grade can be exactly determined. The flatness and parallelism were early visually evaluated. It will be very important to solve the problem using two or more stabilised lasers as the illumination unit instead single He – Ne laser.

References

[1] L. Sałbut, M. Kujawińska, Z. Ramotowski, “Modification of Kösters interferometer for automatization of gauge blocks measurement. SPIE Vol. 3477, 0277 - 786 X/98.

[2] K. P. Birch, M. J. Downs, “An updated Edlen equation for the refractive index of air”, Metrology, v.30, 155-162, 1993

[3] K. P. Birch, M. J. Downs, “Correction to the updated Edlen equation for the refractive index of air”, Metrology v.31, 315-316, 1994

[4] J. E. Decker, J. R. Pekelsky, “Uncertainty evaluation for the measurement of gauge blocks by optical interferometry”, Metrology, v.34, 475-493, 1997