Automation of the Amplitude Measurement Process of Ultrasonic Oscillatory Systems Irradiating Surface

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Abstract—In the article presented results of researches directional on perfecting a stroboscopic measuring method of oscillations amplitude. The obtained results have allowed to create the equipment of automatic amplitude checking and to recommend it for practical application.

I. INTRODUCTION

THE AMPLITUDE OF mechanical oscillation of irradiating surface is the major parameter of ultrasonic action from technological device to a processing medium, and defines efficiency or realization possibility of technological process. It is known, that the greatest efficiency of ultrasonic machining processes is attained, in particular for each process, rather narrow range of oscillations amplitudes. Therefore measuring and control of oscillations amplitude have very important meaning, as at designing, adjustment, testing and repair of ultrasonic technological devices, and at measuring operation modes during technological process. In this connection, perfecting existing and development new methods and means of measuring the oscillation amplitude of irradiating surface is an actual problem.

The analysis of existing methods [1] of measuring oscillations amplitude has shown that they are applicable only for a solution of single metrological problems. Their common limitation is the impossibility deriving of absolute value a measurand without realization of previously calibration under the concrete type of ultrasonic oscillatory system. It makes methods unsuitable for use in exploratory and an industrial practice.

II. THE ANALYSIS OF LIMITATION OF STROBOSCOPIC METHOD. OFFERING THE WAYS OF ITS PERFECTING

Now the stroboscopic measuring method of oscillations amplitude is widely used, permitting to receive absolute value of measurand in a wide range oscillations frequency without previously calibration under a concrete measuring situation.

The essence of a method consists in the following: the ultrasonic oscillatory system is illuminated by the pulses of light clocked with an oscillation frequency [2]. Changing a phase of pulse concerning a phase of oscillation, at observation of ultrasonic oscillatory system a irradiating surface through the microscope with the ocular scale define, at first one, and then other boundary position. Oscillations amplitude defines as half of distances between boundary positions. At the same time, the following limitation is proper this method:

- presence of the subjective accuracy factor of the operator conditioned by participation it during measuring;
- the impossibility of simultaneous observation of two boundary positions that reduces accuracy and increments time of one measuring;
- impossibility of measuring automation.

For removal the discovered limitation it is offered to realize lighting of irradiating surface of a ultrasonic oscillatory system during one oscillation period, not one, as in a base method, and two light pulses forming by various sources, distinguished by color of radiation [3]. A pulse representation frequency to establish so, that the moments of pulse forming one radiation waves length (color) coincide with the moment of maximum displacement of a irradiating surface in one direction, and the moment of pulse forming of other radiation waves length - with the moment of maximum displacement in an opposite direction. At observation in a transmitted light are formed two quickly rotatory a shadowgraph of the irradiating surface, shifted be relative each other on distance, equal to a doubled
value of oscillations amplitude. The scheme of image generation submitted on figure 1.

As long as the human’s eye has a sluggishness, rotatory of shadowgraph not observe. Instead of it one image which can be divided into three sections. The first zone is derivated by imposing of light sections of images and colored in the color generated by addition of their colors. The second zone is derivated by imposing of a light section of one image and a dark section of another. Its width is equal to a half amplitude value. The third zone is derivated by imposing of dark sections of both images. Zones have the precise boundaries, both boundary positions are observed simultaneously.

For realization outcomes processing of measuring in automode it was offered two modes of registration of light fluxes.

The first mode consists in transformation of light fluxes to a digital image, by a photographic camera, and postprocessing of the computer.

![Image](image.png)

1 - The microscope;
2 - trajectory of oscillatory process;
3 - pulsed light sources;
4 – ultrasonic oscillatory system.
Fig. 1. The plan of image generation.

In this case, because of singularities of a human eye color perception, and also the accepted delivery system of color on the screen of the computer, it is necessary to select wave lengths of light sources, from a requirement of their perception as red, green or blue colors of light emission.

The algorithm of a digital image processing consists in the following:

1) The initial digital image is parted on three independent half-tone images, each of which carries the information on density separate color component the color image - red, green, blue. Only two images which color attributes correspond to color of light sources are exposed to the further processing.

2) Above each of two half-tone images, take operation binarization as a result of which each point of the image is represented by a logical zero or logical one. If density of a point less than a defined threshold value - a point is represented by a logical zero. If it is more - logical one. Meaning of a threshold binarization is selected by the experimental way.

3) Above the relevant points of two images obtained in result of binarization, the logic operation «eliminating OR» is taked. In result the binary image which points receive a value logical one there points of initial binary images have various logic meanings. Meanings of a logical zero - where points have equal logic meanings. Since treated images have differences only in the second zone, after execution of the operation, the image will be consisting of a black background and a white band.

4) Definition width of a white band. For this purpose scanning randomly selected horizontal line of the image. For increasing measurement accuracy need scanning several lines and the statistical processing obtained senses.

5) Transformation a bandwidth meaning to meaning of oscillations amplitude, according to expression (1).

\[
A = \frac{1}{2} \frac{B}{B_0} b.
\]

where
- \(B_0\) - the image width of standard length bar, expressed in quantity of image element,
- \(b\) - the width of standard length bar, expressed in millimeters (micrometers),
- \(B\) - the bandwidth expressed in quantity of image element.

For definition of coefficients \(B_0\) and \(b\) also performing previously calibration consisting in registration and count of an image size, created using the standard length bar.

At the same time the processing mode has next singularities:
- the measurement accuracy depends from oscillations amplitude, at that increase of a oscillation range - increases accuracy. It is conditioned by
limitation resolution of the recording device providing transformation to a digital image;

- low speed of the oscillations amplitude measuring process, conditioned by limitation of speed of the device and low capacity of the information transfer protocol between the recording device and the computer;

- attempt increase resolution or speed of the recording device cause increment of requirements to computing ability of the computer used for processing results. That increase cost of mode practical realization and does it economically not justified.

Owing to what this method expediently apply to calibration other measuring means of oscillations amplitude of ultrasonic oscillatory system.

For increase of measuring speed and accuracy designed the second mode. A light flux lapped by an oscillating irradiating pass through a limitative diaphragm, and it is parted by a prism on two equal light fluxes. One of them passes through a color-filter dropping only radiation, having the wave lengths relevant emitted first pulsed light source. Accordingly, the second light flux passes through other color-filter dropping only radiation, having the wave lengths relevant emitted second pulsed light source. Then each light flux decreased on the separate transformer, "brightness - voltage". Both transformers should have equal sensitivity, but only for first - to radiation which waves lengths are equal the emitted first pulsed light source, and the second transformer - accordingly to radiation of the second source. Oscillation amplitude defines on a difference of voltage of registered electrical signals.

The essence of mode submitted figure 2 on which scheme of the light fluxes transformation which are emitted first (figure 2.a) and second (figure 2.b) by the pulsed light sources represented.

For increase of accuracy and reduction of result processing it is necessary to use diaphragms with a rectangular aperture and to orient it so that a direction of oscillating forward movement body coincided with one of a diaphragm legs. In this case the oscillations amplitude is calculated from the following expression:

$$ A = K \cdot \Delta U $$  \hspace{1cm} (2)

where $K$ is a constant, defined during calibrating.

At realization of the second control mode it is necessary to solve the following problems:

- To provide identity two pairs of pulse light sources and transformers "brightness - voltage" having equal sensitivity (or most the close), but for different frequencies and as two color-filters into which transmission band enters these frequencies;

- To make additional calibrating at replacement of any device participating in transformation of light fluxes.

The mode automation of the image processing at its practical realization has allowed increasing efficiency of measuring at the expense of increase of speed and accuracy. It has been reached at the expense of replacement the operation of the filing having restricted resolution and permitting to realize filing in discrete instants, the operation of transformation the "brightness - voltage", permitting to realize transformations a measurand continuously.

### III. CONCLUSION

The offered modes have been practically implemented.

The created devices have allowed realizing measuring of oscillations amplitude of ultrasonic oscillatory system in the automated mode.

The operation testing has confirmed required measurement accuracy, a possibility of measuring process conducting in the automated condition, and has allowed to recommend them for use in research and an industrial practice.
REFERENCES


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