Program improvement of quality of the images at 2D acoustic visualization

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Abstract

The various program methods are offered (linear filtration, processing on special functions with an adjustable weights, color-coding) to improve the images quality at 2D acoustic visualization of solid-state products, which are illustrated on an example of researches of friction pair. Overlapping the acoustic images (AI) with the appropriate optical images (OI) with required scale transformation in addition is realized. The quantitative criteria of an estimation of the characteristics of a contact stain of friction pair are offered.

Keywords: ultrasonic diagnostic complex, acoustic and optical image, filtration, scale transformation, pair of friction.

1. Introduction

The development of computer facilities has resulted in significant improvement of systems of ultrasonic diagnostics. Now at realization of non-destructive testing frequently there is a necessity for reception of the acoustic image with the high resolution. To receive the necessary information at scanning object with use of acoustic waves and to generate its visual image it is obviously possible through systems of ultrasonic visualization.

The methods of ultrasonic visualization already have received wide application in various areas of a science and engineering: non-destructive production quality surveillance, medical diagnostics, diagnostics of materials and products. However, in researches directed on maintenance of reliable functioning of mechanisms, technical diagnostics both control of processes of friction and wear process are important, the application of methods of ultrasonic visualization seems to be new and rather perspective.

2. Estimation of the tribological characteristics

The ultrasonic diagnostic tomography is carried out through the ultrasonic diagnostic complex (UDC), which consists of ehotomoscop ETS-U-02 with ultrasonic piezoceramical transducers (UPT), a videoadapter, a personal computer (PC) with a laser printer and an optical scanner. The mechanical cross section scanning of an object under control placed in a working fluid is carried out with the help of the UPT. The echo-signals received undergo preliminary processing and are displayed on the screen of the monitor echotomoscop as a cross section AI of the object.

From the output of the echotomoscop AI is sent through the videoadapter to the PC. The optical image of the drawing of the examined section of the object is entered in to PC with the help of the optical scanner. Then images are overlapped and processed with the help of a special program.

As a result of comparison of the processed images it is possible precisely to look after interrelation of dynamics of change of AI parameters with the change of friction pair loading.

When friction pair is on loading and rotation there was a luminous contact stain on AI, representing 32 gradation of gray color. Area and intensity of that stain were counted accordingly to listed below algorithm, that allowed to compare changes of received AI to changes of parameters of researched object.

In a product representing the "shaft-and-bush" type friction pair, as it is shown in a fig. 2, a surface of their contact can be effectively diagnosed. If in this area there are cracks or local-intense condition, there is on two - three order a large area in which deformation have changed density and elasticity module of substance. So conditions of reflection of a sound are changing that entail also AI changes. As last is a matrix of 512x512 points with 32 gradation of brightness, it is possible to allocate on it the rectangular containing a contact stain. Brightness for all allocated area according to a ratio further is encountered:

$$I = \sum_{i=1}^{N} \sum_{j=1}^{M} I(X_i, Y_j) \quad , \qquad (1)$$

where M, N - length of the sides of the allocated rectangular, brightness I (X_i, Y_i) - code of brightness of the image point. The size I is represented in arbitrary units of brightness of all rectangular.

If to study dependence of brightness I from the external factors (friction pair loading p, rotation frequency w, etc.) then the criteria of an estimation of tribological properties of such friction pair would arise. Thus the relative dependence seems to be interesting:

$$\Delta I(p, w) = I(p, w) - I(p = 0, w = 0) \quad , \qquad (2)$$

which unequivocally defines the influence of the external factors.

Two remarks should be made. The first chosen rectangular should be inside the second rectangular, if I_{21}(p, w) for addition of crossing of sets of these points is constant, the first rectangular can be narrowed. Thus the process proceeds so long as the condition will not be broken. The size of area subject to operational changes thus is determined. Else process of expansion of the first rectangular should be carried out, until I_{21} will not become a constant. Rectangular can be replaced by any other closed curve. There is some disorder in brightness of points because of echotomoscope features, therefore it is recommended for each point to choose a code $I(X_i, Y_i)$, average for some interval of time.

2. Computer processing of the images

The ultrasonic visualization of friction processes have some difficulties caused by occurrence of false images as a result of reflections and transformations of ultrasonic oscillations in controllable solid-state friction object, for which elimination, the additional digital processing AI is offered.

The various kinds of a linear filtration, processing on special functions with predefined and adjusted weights and color-coding of the black-and-white images [2] were applied to improve the AI quality. Besides the program overlapping AI with its optical analogue was made.

The application of filtration methods was oriented on such tasks as exception of extraneous noise, expression of borders of image elements and correction of its brightness characteristics.

At the decision of a task of noise exception the advantages of a low-frequency filtration overwhelming spatially uncorrelated noise (which contains some higher spatial frequencies in its spectrum comparison with a spectrum of the basic image) were used. In particular, for this purpose the operation of discrete convolution of the initial image with various noise-suppressing masks was used.

Noise smoothing has as a by-effect some blurring of image contours (compare the initial image on fig.1a and result of filtering on fig. 1b), so it was applied in a combination to various techniques of borders expression. Among other the discrete filtration with the high-frequency pulse response (fig. 1c) was used for that.

The same discrete convolution with masks chosen proceeding from a condition of equality to 1 of the sum of their elements was applied to realization of a high-frequency filtration.

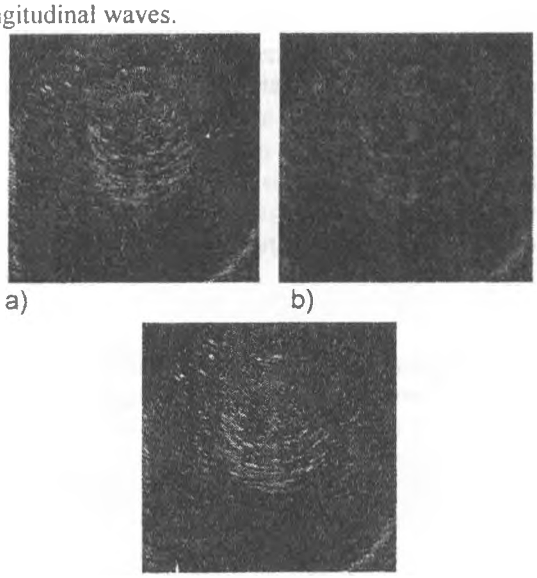
For the greater visual expressiveness the emphasis of borders was accompanied by imposing of the optical image received by scale transformation of the scanned drawing of the examined detail.

In addition to the image filtration the correction of its brightness characteristics expressed in mapping of its intensity meanings on a range, definitely distinguished from initial was made. Linear transformation of intensity that is change of general brightness of the image, was made and also gamma correction, resulting in nonlinear changes of intensity of image elements. Last allowed to correct separate areas of intensity range, achieving more precise emphasizing of required image elements. The final variant of the image is shown in a fig. 2.

Using of color-coded images is associated with feature of human vision, allowing distinguishing the greater number of various color hues, than number of hues of gray color. Hence the transition from black-and-white to pseudo-colors improves the recognizing of low-contrast image elements, and also can be used for visual emphasizing of its separate regions.

Color-coding of the initial images was made in connection to area of a contact stain, the brightness gradation of which received most "hot" color hues (appropriate to gradation of red color), while "heat" of other part of the image decreased with distance.

Use of the optical image imposed on acoustic one allows to discharge the interfering factors, which are the consequence of cross waves occurrence in a solid product, because of what there are false images on AI. The analysis of brightness of the false images on an above mentioned technique can be useful for quantitative criteria of an estimation of physical and tribological characteristics of friction pairs as the transverse waves carry additional information about the contact stain, which cannot be achieved by longitudinal waves.



a) b)

c)

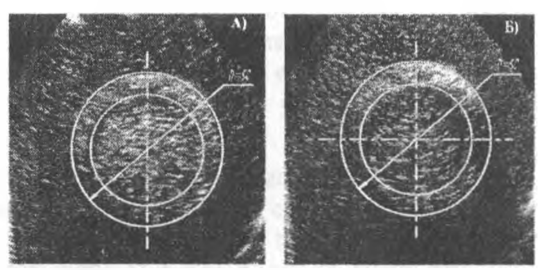
Fig. 1. Application of a linear filtration a) - initial image; b) - result of application of the low-frequency filter; c) - result of application of a high-frequency filter

For the coordination of AI and OI scales it is necessary to reduce the overlapping image size n times ($n=S_m/S_l$, where S_m and S_l are velocities in a material and in a contact liquid accordingly) or to increase the image size in the same proportion. For example, for an aluminum product n = 4.6.

At overlapping AI and OI it is necessary to find two identical points in each of the images. It is obvious, that for AI those are two nearest to emitter. In the worse case there is one, and second is possible to believe the emitter itself. Correctly executed scale transformation makes identical all points of mediums boundary.

Overlapped images are shown on fig. 3.

Fig. 2. Image passed through complex processing.



a) b)

Fig. 3. Images with AI and OI overlapping (AI obtained with different modes of loading) a) Frequency of rotation n=400 min^{-1}; loading P=500 N; b) Frequency of rotation n=400 min^{1}; loading P=2000 N.

The acoustic images were received with the help of the machine for test of materials for friction and wear 2070 SMT-1. The material of the shaft was served by steel 40H. The bush was made of bronze OCS-5-5-5. This materials have found wide application in condensing devices, bearings of sliding and other units of friction. The industrial oil I-40A was used as a working liquid. The ultrasonic transducer fastened with special rig at investigated cell of friction machine.

Conclusion

In the whole set of mentioned above transformations has allowed to achieve much higher quality AI, making it essentially more recognizable. Using of (1) and (2) makes it possible to get a quantitative criterion of solid-state products dynamics examination.

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