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VIBRATION ANALYSIS OF A TUNING FORK OF AN ELECTRONIC WATCH BY SPECKLING

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1. Introduction

Interferometric and novel speckle methods were studied to analyse the mechanical oscillations of a tuning fork of a new design of an electronic watch accurately. For the quantitative investigation of the superimposed movements holographic techniques are very often troublesome. The interpretation of the interference fringes together with the investigation of their accurate location is complicated. Nevertheless, holographic interferometry can be very attractive for a qualitative study of movements. To measure quantitatively the amplitudes of the mechanical oscillation of the tuning fork the speckle phenomenon was found appropriate. When analysing superimposed movements, tilts and in-plane movements can be separated and measured accurately. The results of holographic methods will be discussed together with those obtained by the application of the speckle phenomenon.

2. Measurement of in-plane mechanical oscillations

The application of speckle patterns to study in-plane translations and rotations was studied recently (1-2). Photographing the speckle pattern before and after the in-plane movement of the surface has taken place, will lead to two practically identical, but shifted speckle patterns from which the in-plane translation and rotation can be derived by analysing its optical diffraction effect. Young's interference fringes are obtained when the developed photographic plate is illuminted with coherent light. The fringe spacing is inversely proportional to the translation $\Delta\xi$ (Fig. 1a). A point-by-point analysis of the speckle pattern is useful when the movements of the different points on the object are not equal.

For analysis of harmonic in-plane oscillations of the tuning fork, amplitude and orientation of the movement were obtained first by stroboscopic illumination i.e. the object was illuminated at the extreme positions for instance. In this way the problem is reduced to a simple translation measurement giving cosine fringes in the Fraunhofer diffraction pattern, as previously. Alternatively, the vibratory movements were measured by a single time average exposure of the speckle pattern (exposure over a number of oscillations) (2).

The position probability density function of the speckle pattern is of the form $P_1(\xi) = \dfrac{1}{\pi\sqrt{\varrho^2-\xi^2}}$ as indicated in Fig. 1b where ϱ is the amplitude of in-plane oscillation. The corresponding interference fringes obtained by illuminating the developed film or plate with coherent light are Bessel functions of order zero and first kind as indicated in Fig. 1b. The fringes are seen at an angle twice as large as the exit pupil of the image forming lens when the latter is seen from the image plane.

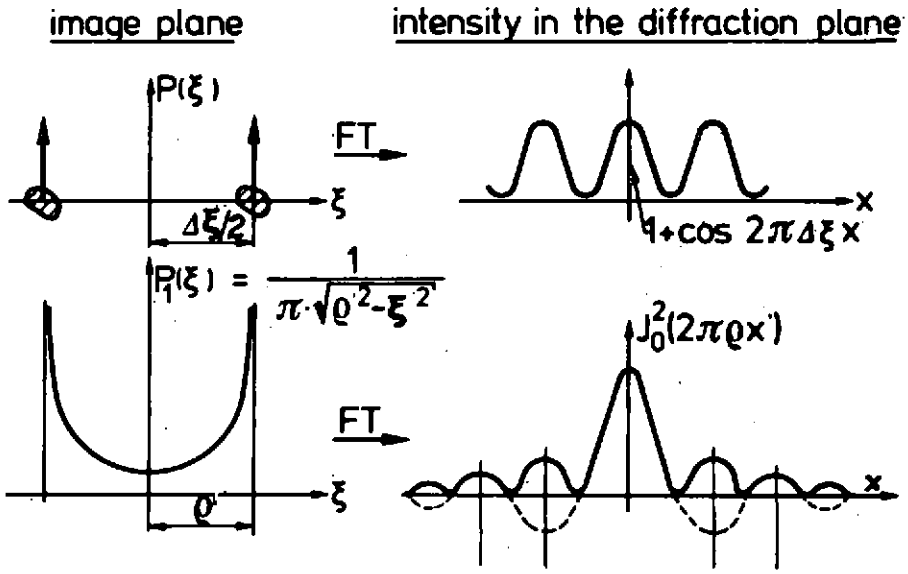

Fig. 1a

Fig. 1b

The useful range for the application of speckling to study in-plane mechanical oscillations is roughly 3 μm < ρ < 500 μm. Furthermore, rigid body displacements parallel to the line of sight had practically no consequences on the accuracy of the in-plane measurements. Small additional tilts (γ < 30 min of arc for an F/2.8 lens) lead to a small reduction of the contrast of the interference fringes only.

3. Measurements of tilts in the presence of in-plane mechanical oscillations

Recording the speckle patterns in the Fourier transform plane before and after a tilt or as a time average exposure leads to cosine or Bessel functions of order zero, respectively, by illuminating the developed plate or film with coherent light (2). This result was very useful for our study, because slight misalignments of the electromagnetic heads resulted in movements out of plane of the tuning fork (tilts). It is due to the fact that a tilt of the object leads to a lateral shift of the practically identical speckle pattern in the Fourier-transform plane proportional to the tilt angle.

Recording the speckle pattern between the image and Fourier transform plane leads to fringes of superimposed movements. By recording the speckle pattern either in the image or Foruier transform plane of the object the analysis of superimposed mechanical oscillations becomes very easy and requires no sophisticated equipment or special treatment of the object. The speckle method is a very attractive engineering tool for vibration-analysis.

References:

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