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ON A MECHANO-OPTICAL METHOD IN FORCE MEASUREMENTS

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Abstract: *The optical techniques are very suited for different investigations concerning the elastic contact between two bodies. Using such an optical method the authors have managed to construct a very simple and useful transducer which could provide different information about the elastic contact. The transducer presented in this paper is specialized for elastic contact force measurements but, using the same principle, it is possible to get any information about the elastic contact.*
Keywords: *transducer, optical technique, elastic contact*

1. INTRODUCTION

The elasto-optical contact properties of two surfaces (reflection and refraction of a light ray at the separation level between two transparent bodies, the propagation of the evanescent wave, the relative topography of the surfaces in contact below the elastic limit) may be used in the field of different measurements successfully. We took the advantage of all these properties projecting an original apparatus whose function is based upon the mechano-optical modulation of a light wave through an elasto-optical contact. Although the apparatus presented in this paper is specialized for elastic contact force measurements, the mechano - optical modulation principle can be used for a wide sort of elastic contact measurements successfully.

2. ELASTO - OPTICAL CONTACT

A plane prism with its surface S' is continuously approached to the surface S on which the total reflection takes place (Newton's experience) [1], fig.1.

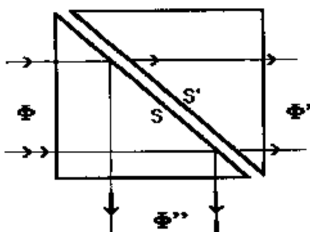

Figure 1

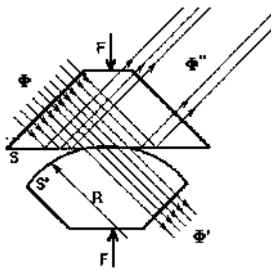

Figure 2

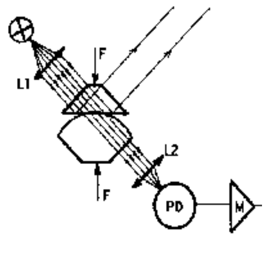

Figure 3

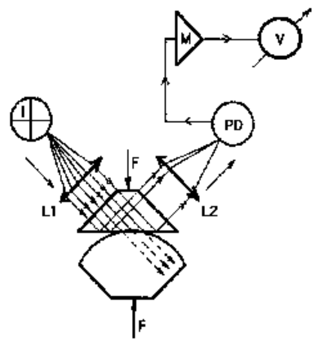

Figure 4

From a certain distance between the two surfaces S and S', a light ray through S' will occur while the reflected light ray intensity will diminish. If the surface S' is convex (or the surfaces S and S' are not perfectly plane) and the both bodies in contact are pushed by a force F, then S and S' will have an elastic deformation. The elastic contact area between S and S' depends upon the value of force F, fig. 2. In this way, the transmitted light flux ϕ' increases while the reflected flux ϕ'' diminishes proportionally if the force F acts. Due to the elastic properties of the material we may consider that the optical contact area depends upon the value of force F. This relationship may be written as

$$A=A(F) \quad \textbf{(1)}$$

where A is the optical contact area. The shape of the surfaces in contact (S and S') will determine a certain dependence between A and F. For example, if the surface S is plane and S' is spherical, then the relationship (1) has the following form, [5]:

$$A = \text{®}\left[0.9086\left(FR\text{¦}\right)^{(1/3)}\right]^{2} \qquad \textbf{(2)}$$

where R is the sphere radius, F is the force acting on the prisms and

$$\text{¦} = \frac{1-\text{«}_1^2}{E_1} + \frac{1-\text{«}_2^2}{E_2}, \qquad \textbf{(3)}$$

where «_1 and «_2 are the Poisson's coefficients for the materials of the prisms in contact, E_1 and E_2 are the elastic modules in tension or compression for the involved materials. The relationship (2) may be represented in a simple form as

$$A = KF^{\frac{2}{3}} \qquad \textbf{(4)}$$

where K is a constant. Through an adequate modelling on computer we could obtain a certain shape of the surfaces in contact as the relationship (4) to become linear. In accordance with those presented above, the transmitted light flux (fig. 2) is given by

$$\text{c}' = \frac{\text{c}A(F)}{A_s} \qquad \textbf{(5)}$$

(if the surface S is uniform lighted), and the reflected light flux is

$$\text{c}'' = \text{c}\left(1 - \frac{A(F)}{A_s}\right) \qquad \textbf{(6)}$$

where A_s is the surface S area and ¤ is the incident flux.

3. APPARATUS PRINCIPLE

From those presented up to now it follows that reflection and transmission of a light ray that passes through an optical system (composed of two transparent bodies in contact) depend upon the size of the contact surface area. This connection may be used in the following scheme, (fig.3). A luminous flux emitted by a light source (1) passes through a len (*L1*) and then through the two bodies in contact (*P1* and *P2*). A part of this flux is reflected and another part (that depends upon the size of the contact surface area) gets to a converging len (*L2*). Different values of the force F will determine different values for the size of the contact surface area, (1). In this way a direct connection between the force F and the light flux on the len (*L2*) is created. A photodetector (*PD*) analyses this signal which will be then amplified by the amplifier (*M*). With the same principle we could use another scheme as that represented in fig. 4. In this case only one of the two bodies in contact will be transparent while the other one is opaque. The reflected light flux will be given by the relationship (7).

$$\text{c}'' = \text{c}\left(1 - a\frac{A}{A_s}\right) \qquad \textbf{(7)}$$

where a is the absorption coefficient for surface S', ($0<a<1$). Using the principle presented above the authors have materialized an original mechano-optical transducer in which the two surfaces in contact were one plane and the other one spherical.

4. CONCLUSIONS

The use of optical methods for the elastic contact measurements has some important advantages such as: the possibility to minimize the size of the transducer using optical fibres; different measurements in the fields of low values; a connection through optical fibres between transducer and the central data collector eliminates the possibility that the transmission to be influenced by the external electromagnetic fields. We took the advantage of all these projecting an original transducer whose function is based upon the mechano-optical modulation of a light wave through an elasto - optical contact. The principle presented above for elastic contact force measurements can be generalized for the whole sort of information regarding the elastic contact.

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