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Mathematical Modeling of Elastic Hysteresis Phenomenon in Round Plates in Presence of Residual Tension

T.A. Baltayev^{a,*}, A.V. Korolev^b, T.M. Mannapova^a

^a West Kazakhstan agrarian – technical University named Zhangir Khan, Uralsk 090014, Republic Kazakhstan

^b Yuri Gagarin State Technical University, Sartov 410054, Russian Federation

Abstract

The phenomenon of elastic hysteresis arising in a round metal plate which is rigidly fixed on the edge under the influence of cyclic plate of external loading which is evenly distributed on a surface was modeled in the article. It was shown that saved-up residual deformation asymptotically strives with the increase in number of loading cycles for the value depending on initial internal potential energy of residual tension in plate material. The offered mathematical model can be used at the production of various pressure sensors in which a round metal plate is a sensitive element.

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Nomenclature

φ	central angle covering elementary site
$u(z, r)$	specific potential energy of deformation saved up in body volume unit is equal
$\sigma_r(r)$	normal radial stress operating at r distance from the plate center, Pa
$\sigma_\varphi(r)$	peripheral normal stress operating at r distance from the plate center, Pa
$\tau_Q(r)$	shearing stress, operating at r distance from the plate center, Pa
Z	distance from neutral layer of plate, mm

* Corresponding author. Tel.: +7-747-169-99-96; fax: +7-905-326-98-92.

E-mail address: statmail_87@mail.ru

$M_r(r)$	intensity of radial bending moment per a unit of cylindrical section length of plate, N·mm/mm
$M_\varphi(r)$	intensity of peripheral bending moment per a unit of cylindrical section length of plate, N·mm/mm
$Q(r)$	intensity of radial lateral force per a unit of cylindrical section length of plate, N/mm
δ	plate thickness, mm
d	plate diameter, m m
μ	the poisson ratio
λ_o	deformation of plate center, m m
E	Young's modulus, Pa

Round elastic plates are widely applied in various automatic devices and devices based on measurement of liquid or gas pressure. One of the problems of such devices production is instability of indications because of elastic hysteresis action of plate material leading to its residual deformation. Despite numerous researches of stabilization process of detail [1-16] elastic properties and the ways of development of residual tension [14-16] details removal from the material, the problem of device indication accuracy increase remains not solved. It is important for the specified problem solution to reveal the mechanism of elastic hysteresis of round plate and to offer its mathematical model.

The round plate is usually rigidly fixed in pressure devices on external contour and works under pressure of liquid or gas which is evenly influencing its surface (see Fig. 1).

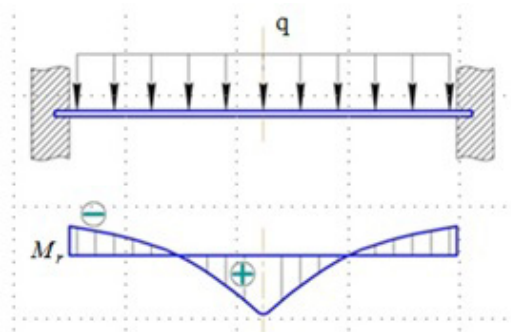


Fig. 1. design model.

We allocate elementary site for a circle with radius r of plate with the square

$$ds = r dr d\varphi \quad (1)$$

Potential energy of deformation acts on this site and it's equal:

$$dU(r, \varphi) = u(z, r) ds \quad (2)$$

Specific potential energy of deformation saved up in body volume unit is equal:

$$u(z, r) = \frac{1}{2E} \left[\sigma_r(z, r)^2 + \sigma_\varphi(z, r)^2 - 2\mu\sigma_r(z, r)\sigma_\varphi(z, r) + 2(1 + \mu)\tau_Q(r)^2 \right] \quad (3)$$

Normal radial stress operating at r distance from the plate center, Pa, equal:

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