CALCULATION OF ELASTIC CONSTANTS OF THE TORSION BARS WITH HELICAL ANISOTROPY USING THE METHODS OF OPTIMIZATION THEORY

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Summary *The object of scientific research is the torsion bar of the Magnetosensitive Element (MSE) of Torsion Magnetometer (TM), which is a part of the geophysical complex GI-MTS-1. This is a torsion bar with helical anisotropy, performed as a braid made of Kevlar filaments (fibers). The Elastic Constants of the torsion bar are calculated, using an algorithm for computing the elastic constants of the cable, which is based on analysis of errors of modules determination and minimization of the functional f (E_1, G) in preset intervals v.*

INTRODUCTION

There exists a range of devices, in sensitive elements (SE) of which threads, suspension or stretching are used. Among them are torsion devices (for example torsion balance, several magnetometers), string accelerometers, seismographs, etc. Main requirements for a SE are imposed upon: linearity and unambiguity of static characteristic, high sensitivity and resolution capability; repeatable accuracy in time, load tolerance of static characteristics, minimal inertia; minimal external influence (temperature, vibration, etc.); chemoresistance; simplicity and manufacturability of design; interchangeability (repeatability of characteristics); ease of installation and operation activity. The type of selected SE is depends on system accuracy requirement, its destination and operation conditions.

To improve performance of devices of this type, it was suggested of making SE in a form of braid, which comes from the theory of Helically Anisotropic solid. Filaments of Kevlar threads have been selected as a raw material.

The device for manufacturing of the particularly thin ultrastrong torsion bars has developed. For the time being, they are used as a suspension of the magnetosensitive element (MSE) of torsion magnetometer (TM), which is a part of the geophysical complex GI-MTS-1 (SPbF IZMIRAN). The main advantage of TM with this MSE is a recording of the magnetic fields and their variations in the frequency range of $0\ldots15$ Hz, with the meansquare noise level not exceeding 1 [$pT/\sqrt{Hz}$], however device has low climatic factors (temperature, moisture) dependence and have increased resistance to dynamical load during transportation (more the 15g).

CHARACTERISTICS OF TORSION BARS

Torsion bars obtained by means of device are made of Kevlar filaments. The synthetic high-modulus yarns designed by the Russian scientists and engineers are rated as para-aramid fiber. Yarns are unique by its properties: high tensile strength, high modulus of elasticity, low elongation to break, high resistance to thermal and thermo-oxidative destruction, resistance to chemical reagents and decent compatibility with binders of different types. Yarns are not toxic or highly explosive, not combustible; they start burning at direct contact with the open fire and stop burning at its dying. Yarns may be stored for a long period without loosing characteristics and are under minor change hereby when being wet. They are stable to a long staying in water and are biologically stable.

Photographs of torsion bars are shown in Fig.1. The envelope of the cross-section of torsion bars is an ellipse with longer axis of 0.04 mm and shorter axis of 0.03 mm, the total length - 100 mm, the density of braiding –10 knots/mm, specific breaking load – 1.5 N.

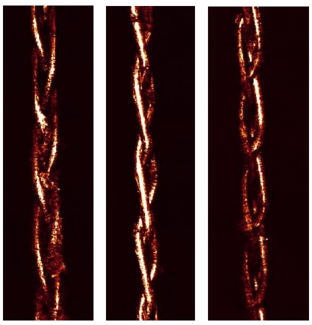

Fig. 1. Photographs of torsion bars

CALCULATION OF ELASTIC CONSTANTS OF THE TORSION BAR.

Testing by loading the torsion bar along the ξ axis should be conducted to determine its elastic constants. This would be impossible when applied to the torsion bar. Let us examine system of equations 1 as the initial system for determination of the elastic constants E_1, G, ν.

Actually, this is an algebraic system of equation, were the values of a_{ij} are given:

$$\alpha_{11}E_1 = G(9\phi_1 + 18\phi_2) - \frac{1}{2-\nu_1}E_1 9\phi_2 + E_1 - 3\phi_1 E_1;$$

$$\alpha_{12}E_1 = -G(3\phi_1 + 12\phi_2) + \frac{1}{2-\nu_1}E_1 6\phi_2 + E_1\phi_1;$$

$$\alpha_{22}E_1 = G(\frac{tg^2\alpha_0}{2} + 8\phi_2) - \frac{1}{2-\nu_1}E_1 4\phi_2; \qquad (1)$$

where $\phi_1 = 1 - 2ctg^2\alpha_0 \ln\sec\alpha_0;$

$$\phi_2 = \frac{1}{2}\sin^2\alpha_0 - 1 + 2ctg^2\alpha_0 \ln\sec\alpha_0;$$

α_0 - the angle of incline of the helical lines with respect to the z axis of the cylinder.

E_1^*, G_1^* and ν_1^* – the integral elastic constants of Helically Anisotropic rod;

Then we found minimum values of the functional $f = \sqrt{E_1^2 + G^2}$ within each interval for given values $0 \le \nu \le 0{,}5$.

CONCLUSIONS

The torsion bar of the Magnetosensitive Element (MSE) of Torsion Magnetometer (TM) is a torsion bar with helical anisotropy, performed as a braid made of Kevlar filaments (fibers). The torsion bar of the MSE is made of three strings with the help of The Device for manufacturing torsion bars with Helical Anisotropy UISAT-1. The Elastic Constants of the torsion bar are calculated, using an algorithm for computing the elastic constants of the cable, which is based on analysis of errors of modules determination and minimization of the functional f (E_1, G) in preset intervals ν.

In order to execute the assigned task elements of the theory of Helically Anisotropic solid and the methods of optimization theory, as well as modern software MatLab were used. The results of scientific research which will be used for selection optimally parameters of the torsion bar of the MSE of TM, which is a part of the geophysical complex GI-MTS-1.

References

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