Development of Seismic Accelerometers with Bending Deformations of the Sensing Elements

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The authors present the basic requirements and principles for the design of highly – sensitive piezo-accelerometers which have bending bimorph elements supported by central cylindrical rods. The technique presented for the design of piezoelectric sensors with sensitive elements subjected to bending deformations allows one to optimise the assembly parameters of the sensors. Calculations agree well with experimental data. The technique considered has wide versatility and it is physically illustrative for the design not only piezo-accelerometers but also of other types of piezoelectric sensors of the mechanical values.

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1. INTRODUCTION

One of the directions of piezoelectric instrument – making associated with the construction of sensors with high or superhigh sensitivity is based on the use of sensitive element bimorph and multiplayer plates which are subjected to bending deformations. Such sensors are used basically to obtain detailed experimental information about the parameters of elastic (acoustic) waves which travel in various media. They are also used to study the features of various massive and large-scale objects and constructions over wide amplitude and frequency ranges. The signal's amplitude can range from $(10^{-5} - 10^{-3})$ g up to several g, and its frequency can range from 0.1 Hz up to 100-1000 Hz. In this paper we consider the problems of the design of highly sensitive piezoelectric accelerometers, based on the use of the bending deformations of the sensing elements. Seismic sensors of this type and modern means of signal processing allow one, in most cases, to obtain the required characteristics for measurements. The combination of the parameters (sensitivity, dimensions, mass, resolution, etc.) of such kinds of sensors essentially allows then to surpass analogue types which are based on other sorts of piezoelement deformations (compression-tension, shear). The relatively large electrical capacitance of bimorph and multiplayer plates (with units – tens of nanofaradas) allows the use of long cable lines (tens – hundred metres) to the secondary amplification – transformation equipment with negligible deterioration of the signal/noise ratio. This is of no small importance for dangerous objects (such as explosive material storage, etc.) where the installation of control – measurement devices with external power sources is not allowed.

However realisation of high sensitivity (up to 1 V/g) usually results in an increase in the scatter in the sensor parameters (up to 20-30 %). This is due to the use of highly effective ferroelectricsoft materials (piezoceramics TsTS-19, PKR-1) which are sensitive to the influence of various physical factors (temperature, pressure, etc.) and high mechanical stresses of the sensing elements (up to several Mpa). These factors and high stresses cause instability in the sensor parameters. Therefore, in the design of seismic sensors a rational selection of the assembly parameters and sensing element materials is needed.

The present market for highly sensitive piezoelectric accelerometers is rather small (see Table 1)[1-12]. Most high-sensitive piezoelectric accelerometers manufactured are one-component sensor types with built-in preamplifiers

RFNC-VNJIEF produced high-sensitive (seismic) piezo-accelerometers (models AP23-AP25 and AP34-AP36) which have high transformation coefficients (up to 1 V/g) and are designed for the measurement of low level accelerations. Such types of sensors can be used for engineering constructions, industrial equipment diagnostics and for seismo-prospecting.

The design of highly sensitive piezoelectric accelerometers is based on the use of bending deformations of sensing elements in the form of bimorph (multilayer) membranes. The technique presented for the design calculations for piezoelectric sensors with sensitive elements subjected to bending deformations allows one to optimise the assembly parameters of the sensors.

2. DESIGN PRINCIPLES FOR PIEZOELECTRIC SEISMIC ACCELEROMETERS

A piezoelectric sensor may be defined to be a mechanical-electrical transducer which transforms the mechanical energy of oscillations of the test object surface (or liquid medium particles) into the energy of an electrical signal for further processing. This definition differs from that widely used and given in reference[4], the term "sensor of physical values". It includes parts without which the transformation function loses its completeness and definiteness, e.g., a preamplifier which provides on output electrical impedance which matches the input impedance of the amplifier, filters, etc. Below we will use the term "sensor" to refer to a piezoelectric transducer with a cable and input circuits of the amplifying-trans-