HIGH SENSITIVE PIEZO-ACCELEROMETERS

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One of the most perspective tendencies of piezoelectric instrument industry, associated with the creating of very high sensitive sensors is based on the use of bimorph and multi-layer plates, which undergo deformations of bending, as a sensitive element. In the VNIIEF it was developed a series of sensors for different applications. The seismo-accelerometers of "AP" type and the three-component accelerometer sensor, are described in this paper. They allow one to measure very weak signals (down to 10^{-6} g) in a wide frequency range (from 0,2 Hz up to 2,5 kHz). Characteristics (sensitivity, dimensions, mass, etc.) of such sensors exceed essentially their analogues, which use other types of deformation of piezo-element, e.g. compression-tension or shift deformation. Due to the high metrological characteristics and reliability these seismo-accelerometers of AP type and the three-component sensor may find many applications in vibration diagnostics and in engineering seismo-prospecting.

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The following table contents the performance attributes and form and arranging factors of produced at VNIIEF piezo-accelerometers with the curve oscillations. As an illustration of the using of such sensors the typical oscillogram of the ground accelerations under carrying out of small-scale explosive tests at RFNC-VNIIEF is presented in Figure 1.

One-component seismoaccelerometers AP are designed in six modifications, differing by the mode of fastening on the controlled object: with the help of a thread stem (AP25, AP34, AP35) or and adhesive mode (AP23, AP24, AP36).

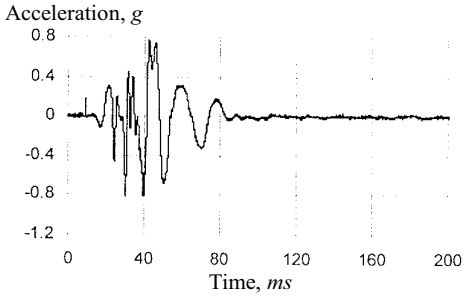

Fig.1. Typical oscillogram of the ground accelerations generated by small-scale explosion, recorded with seismo-accelerometer AP36.

Table. Basic technical characteristics of unicomponent and three-component high-sensitive piezo-accelerometers.

Characteristics	Type of piezo-accelerometer			
	AP23 (AP34)	AP24 (AP35)	AP25 (AP36)	Three-component transducer of acceleration (TCA)
Type of sensitive element	bimorph plate			
Charge sensitivity, mV/g	1000	250	35	20
Amplitude range, g	10^{-6} – 10	10^{-5} – 50	10^{-4} – 100	0,01 - 100
Frequency range (± 10%), kHz	0,0002 – 0,4	**0,0002 – 1**	**0,0002 – 2,5**	0,005 – 0,5
Mounted resonance frequency, kHz	1,2	2,5	6,5	6,5
Temperature range, °C	-60 - +100		-40 - +80	
Mode of fastening on the controlled object	thread or adhesive mode of fastening (according to the modification)		with using of three bolts M5	
Dimensions, mm	**∅24×25** (turn-key 24×25)	**∅24×17** (turn-key 24×17)	**turn-key 24×14** (∅24×14)	∅66,7×44,3
Weight, gram	**80 (85)**	**25 (30)**	**25 (20)**	150

Typical design schemes of the seismoaccelerometers are presented in Figure 2 [1-4]. Piezo-element 1 is made as a thin disk, at the face surfaces of which the electrodes are superimposed. In the seismoaccelerometers AP23, AP24, AP34, AP35 the inertial element, consisting of two parts 3 and 4, is pasted to the elastic element 2. The cable is soldered in the elastic element 2 by means of wire band, which wraps the cable screen. Internal conductor of the cable is soldered on the piezoelement 1. The elastic element 2 with the soldered cable and pasted piezoelement and inertial element is placed into the lid 6, which is welded on the housing 5. The cable outlet place is isolated by rubber bush 7. Anti-vibration cable of AVKT-6 type with external isolating facing is used to outlet the electric signal. There is no inertial element in seismoaccelerometers AP25 and AP36; distributed masses of piezoelement 1 and elastic element 2 play as inertial elements.

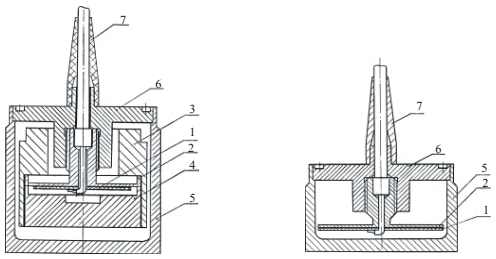

Fig.2. Design of seismoaccelerometers AP:
a – with inertial element, fastened on the external contour of the elastic element (AP23, AP24); **b** – without inertial element (AP25).
1 – piezoelement; 2 – elastic element; 3 – top part of the inertial element; 4 – bottom part of the inertial element; 5 – housing; 6 – lid; 7 – bush.

Seismoaccelerometers of AP type and modern means of processing of different signals allow to provide measurement of very weak mechanical signals (down to 10^{-6} g) in a wide frequency range (up to 2,5 kHz). Such seismoaccelerometers exceed their analogues, that use other types of deformation of piezo-element (compression-tension, shift), on the aggregate of their characteristic (sensitivity, dimensions, mass, resolution, etc.) essentially. However, realization of the high sensitivity (up to 1 V/g) leads, as a rule, to increase of the seismoaccelerometer characteristics dispersion (up to 20-30 %). First of all, it is associated with the usage of high effective Ferro-soft materials (piezo-ceramics TsTS-19), subjected to the influence of different physical factors (temperature, pressure, etc.), and with high mechanical stresses of the sensitive element of the sensor (up to some MPa), that tends to the instabilities of the seismoaccelerometers parameters. Therefore, there is needed to make an efficient choice of their design and arranging parameters and materials of the sensitive element.

Three-component accelerometers (TCA) is based on a scheme (Fig. 3), that uses a curve deformation of sensitive element with central cylindrical support. Such type of converter made in practice a good showing as a relatively stable electro-engineering device in the design of seismoaccelerometers AP25 and AP36. Such converter was, for example, used at RFNC-VNIIEF under developing of resonance knock sensors for automobile engine control systems [5]. These converters are characterized by high mechanical strength, stability of metrological characteristics in a wide temperature range, high reliability and absence of failures, and prolonged life time.

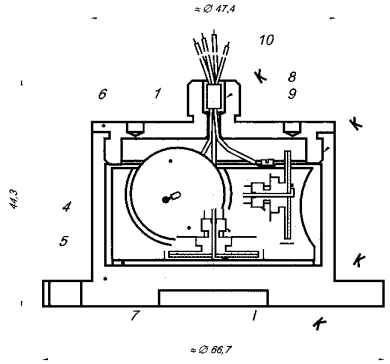

Fig.3. Design of three-component transducer of acceleration:
1 – sensitive element; 4 – isolating layer; 5 – housing; 6 – lid; 7 – support; 8 – conductor; 9 – screw; 10 – cable.

Sensitive elements 1 of three-component accelerometers (TCA) are fastened in three perpendicular directions on the support 7 with the help of thread stems. Three-component sensitive unit is rigidly fastened on the base of the bottom part of housing 5 through the isolating layer 4, that provides the electrical uncoupling of the support 7 and housing 5. The electrical signal is taken from the piezo-element by means of cables 10, soldered onto the external plates of piezo-elements. The conductor 8 is fastened on the support 7 with screw 9. Cables 10 and conductor 9 are fastened on the lid 6 by means of glued in band.

Typical amplitude-frequency response of the three-component accelerometer shows that TCA has the resonance at about 6 kHz and the working frequency range to 3 kHz. TCA may be completed with screwed on electronic unit, which provide the preliminary processing of data: signal amplification, conversion to digital signal, and recording of registered information. Due to the high metrological characteristics and reliability this type of three-component accelerometer can be used in multi-channel systems of vibration diagnostics of equipment at power-production as well as oil and gas transportation plants. It can be also effective in engineering seismo-prospecting and in other applications.

CONCLUSION

In the VNIIEF it was developed a series of seismoaccelerometers of “AP” type for different applications. They allow one to measure very weak signals (down to 10^{-6} g) in a wide frequency range (from 0,2 Hz up to 2,5 kHz). These seismoaccelerometers of AP type and the three-component sensor may find applications in multi-channel systems of vibration diagnostics and in engineering seismo-prospecting.

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