362. Method and equipment for testing of piezoceramic transducers manufacturing quality

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Abstract. The paper presents new testing method of piezoceramic transducers, which are used in innovative ultrasonic flow and heat metering devices. The equipment and specialized software is designed to implement fast, automatic and reliable diagnostic of piezoceramic transducer and control transducer's manufacturing quality. The diagnostic equipment and testing approach was used while investigating transducer parameters changes during their temperature shock tests. These investigations allowed optimizing the design of ultrasonic piezoceramic transducers and minimizing their manufacturing cost.

Keywords: Piezoceramic transducer testing, manufacturing quality control, quality test equipment.

Introduction

Advanced transducer manufacturing technology and associated instrument electronics led to the introduction of commercial products that provide capabilities for material and manufacturing quality analysis of piezoceramic transducers. Batch production implementation of the ultrasonic piezoceramic transducers requires optimal control of being manufactured transducers parameters, manufacturing process and influencing factors. The manufacturing process of the transducers may be influenced by the type of used adhesives, curing temperatures and duration, etc. The quality of the transducer is predetermined by various parameters, which may undergo unpredictable change during the manufacturing process. As example, may be considered changed parameters of the transducer components or used in manufacturing process additional materials, coming from different producers or changed working regimes of the manufacturing process and etc.

There are known few standardized methods for ultrasonic transducers testing which are used by the most manufacturers of the piezoceramic transducers [1,2]. These methods are based on the measurement of different characteristics of the transducers, such as electric impedance, beam profile, frequency response, time response, relative pulse echo sensitivity [3]. The different methods can be used depending on the aims of manufacturers. In order to perform fast and reliable testing of piezoceramic transducer quality, as well as to control the factors, which influence the manufacturing processes, the method suitable for automatic implementation must be chosen. Such methods could be based on the fast measurement of frequency (momentary and central frequency) and amplitude of the echo signal by time-of-flight measurement technique. The results of the measurement allow us to derive practically all important characteristics of the ultrasonic transducers [3,4].

Such equipment was designed and made by “Axis Industries Ltd” (Kaunas, Lithuania) and automated manufacturing of piezoelectric transducers was implemented in mentioned company. The ultrasonic transducers manufactured by “Axis Industries Ltd” are used in batch production as components of new patented ultrasonic heat and water meters [5,6].

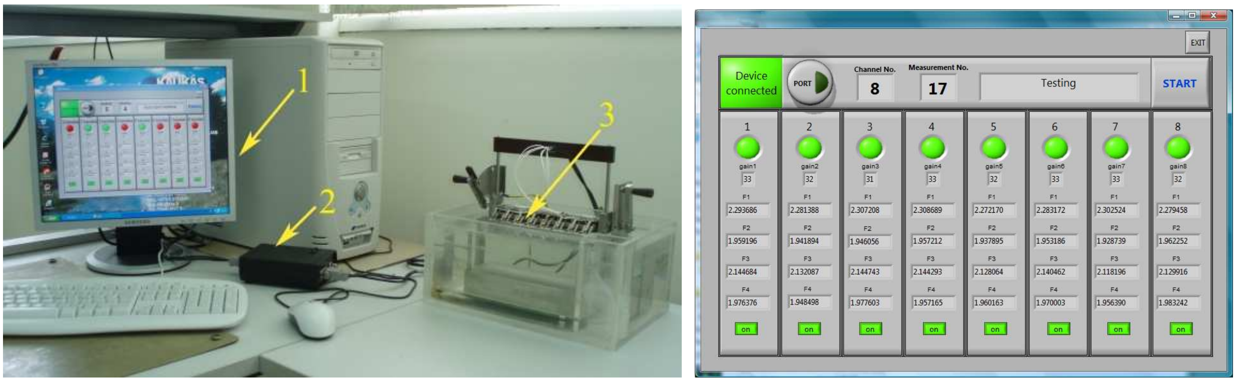
Methods and equipment

The operation algorithm and conception of the automatic test equipment for ultrasonic transducers are:

- being tested transducer is excited by electrical pulse, which generates ultrasonic wave in the water (in testing bath). Reflected ultrasonic signal is received by the same transducer;
- vibration period and amplitude of the received signal are measured;
- results of the measurements are processed by personal computer (PC) and decision on quality of the transducer is taken;
- obtained results are stored in PC's memory;

- up to 8 ultrasonic transducers, placed in the water bath, are tested in series.

The equipment for transducer's parameters testing consists of measurement block (device for parameters measurement), a bath (water tank for transducer mounting) and computer with application software, Fig. 1, a – general view of the equipment, b - screenshot of the used application software for transducers' testing.



a b

Fig. 1. Equipment for ultrasonic piezoelectric transducer testing: a) equipment photo, where 1 is PC, 2 is device for transducer parameters measurement, 3 is water-filled tank; b) is screenshot of the application software used for transducers' testing

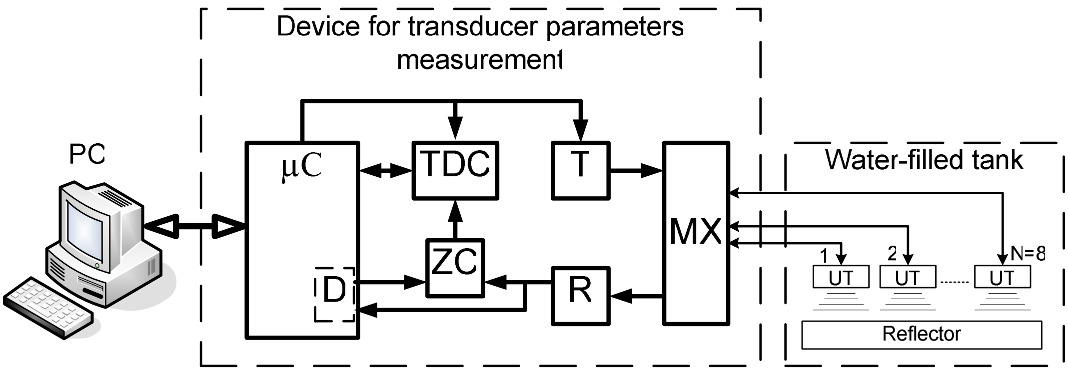


Fig 2. Structural diagram of ultrasonic piezoelectric transducer testing equipment: *μC* – microcontroller, TDC – time-to-digital converter, *T* – transmitter, *R* – receiver, MX – multiplexer, *UT* – ultrasonic transducer, *ZC* – zero cross comparator, *D* – signal detector, *PC* – computer with application software

Fig. 2 presents the structural diagram of the ultrasonic transducers' testing equipment, comprising: *μC*– microcontroller, *TDC* – time- to-digital converter, *T* – transmitter of the excitation signal, *R* – receiver of the signal, *MX* – multiplexer (which respectively turns on the being tested transducer), *UT*– ultrasonic piezoceramic transducer (up to 8 units is possible.), *ZC* – zero cross comparator, *D* – signal detection comparator. *MC* defines start of the measurement cycle and transfers corresponding start signal to the transmitter *T*. The transmitter forms excitation signal, which is send to one of the being tested ultrasonic transducers *UT*. Mentioned transducer *UT* emits ultrasonic signal, which goes back from the reflector and the echo signal is received by the same transducer *UT*, amplified in the receiver. The zero cross moments of the received signal are fixed by the *ZC* (up to 5 zero cross moments). *TDC* measures duration of the vibration half-period of the received signal and transfers them to the microcontroller *μC*. Microcontroller determines the amplitude of the received signal by the parameters of programmed amplifier. Measured data of both the periods of signal vibration and amplitude are transferred to PC, where measurement results of each transducer are processed statistically, stored in database and the decision is made regarding the quality of the being tested transducer.

Results

Ultrasonic transducers' testing equipment is used for automatic control of piezoceramic transducer parameters and their flaw detection. The results of the transducers' testing are stored in the database. Obtained data later can be used for the analysis of the factors, which have influence on manufacturing process as well as for the optimisation of the manufacturing process, having the objective to minimize manufacturing time. The achieved duration of quality testing of one transducer approximately takes 15 s.

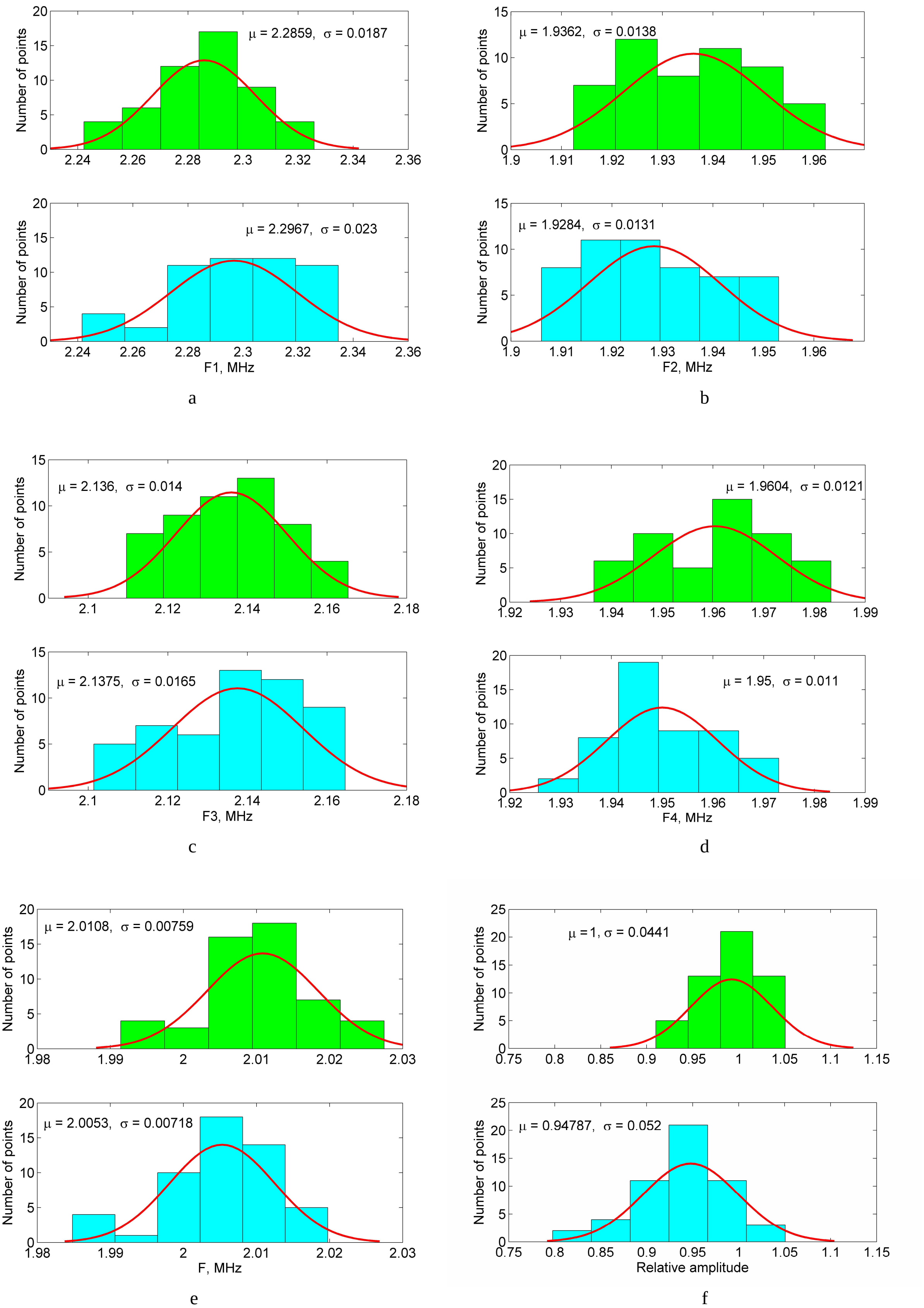


Fig. 3. Changes in transducer parameters affected by temperature shock tests: distribution changes of momentary frequencies F1 (a), F2 (b), F3 (c), F4 (d), central frequency *F* (e) and relative amplitude of the echo signal (f). (Parameters distributions before and after the tests are presented in upper and lower figures respectively)

Table 1. Changes of mean value and standard deviation of the transducer parameters (relative amplitude of echo signal, momentary frequencies (F1, F2, F3, F4) and central frequencies (F)) affected by temperature shock tests

Parameter	Relative amplitude	F1 [Hz]	F2 [MHz]	F3 [MHz]	F4 [MHz]	F [MHz]
μ (before test)	1	2.2859	1.9362	2.1360	1.9604	2.0108
μ (after test)	0.94787	2.2967	1.9284	2.1375	1.9500	2.0053
Changes of μ [%]	-4.48	0.47	-0.40	0.07	-0.53	-0.27
σ (before test)	0.0441	0.0187	0.0138	0.0140	0.0121	0.00759
σ (after test)	0.0520	0.0230	0.0131	0.0165	0.0110	0.00718
Changes of σ [%]	17.91	22.99	-5.07	17.86	-9.09	-5.40

Mentioned above testing equipment was used to evaluate the quality of new experimental batch of ultrasonic transducers performing temperature shock tests. For experimental analysis 52 pcs. of transducers have been taken and parameters (momentary vibration periods, central frequency of transducer and relative sensitivity) have been measured. After that, 15 temperature shocks have been applied on the tested transducers, placing them into the thermostat and raising the temperature up to the 150^0 C ($\pm 5^0$ C). The transducers were left at this temperature for 3 hours. After the heating, transducers were left to cool at room temperature 20 ...25^0C.

The changes of transducers parameters, measured before and after temperature shock tests, are given in Fig. 3 and Table 1, where the variations and of measured parameters (relative amplitude of echo signal, momentary vibration frequencies (F1, F2, F3, F4) of received signal and medium (central) frequency (F)), their distributional laws, medium values (μ) and standard deviations (σ), influenced by impacts during the measurements, are presented

Conclusions

Paper presents automatic test equipment for ultrasonic transducers. This equipment is used to test parameters of new ultrasonic piezoceramic transducers during batch manufacturing, and to control manufacturing processes of the transducers. This equipment allows reliable and rapid estimation of transducers' qualitative parameters (i.e. frequency of vibrations, sensitivity), by stored in the database testing results. Testing procedure of one transducer takes approximately only 15 s.

Obtained results of temperature shock tests showed, that changes of transducers' parameters, caused during the testing procedure, are negligible and therefore cannot affect changes in metrological characteristics of manufactured ultrasonic flowmeters [5,6]:

- changes in central vibration frequency of the reflected signal did not exceed 0.5% for mean value and 6 % for standard deviation respectively;
- the changes in relative amplitude did not exceed 5% for mean value and 20 % for standard deviation respectively
- the changes in momentary vibration frequencies of the reflected signal did not exceed 6% for mean value and 25 % for standard deviation respectively (Table 1 and Fig. 3).

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