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Soft- and hardware system in devices measuring deformation parameters in solids

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The research resulted in design and development of an original soft- and hardware system which digitizes the analog signal and provides multichannel data collection from strain gauge sensors on the base of a 32-bit microcontroller. This system allows to conduct mechanical tests of solids for tension (compression), and also to control conditions of an experiment (temperature, magnetic field, etc.). The designed complex also provides determining and studying of activating parameters of plastic flow in metals and alloys at tests for tension. The registration speed of deformation processes can reach about 10^{-3} c^{-1}, and accuracy of measuring no less than 10 bits of useful signal.
Keywords: mechanical tests, strain gauge, microcontroller, ADC, mechanical properties, solid.

Разработан и создан оригинальный программно-аппаратный комплекс оцифровки аналогового сигнала, обеспечивающий многоканальность сбора данных с тензометрических датчиков на базе 32-х разрядного микроконтроллера. Данная система позволяет проводить механические испытания твердых тел на растяжение (сжатия), а также контролировать условия эксперимента (температура, магнитное поле и т.п.). Созданный комплекс также дает возможность определять и изучать активационные параметры пластической деформации в металлах и сплавах при испытаниях на растяжение. При этом скорость регистрации деформационных процессов может составлять порядка 10^{-3} $с^{-1}$ и точность измерений не менее 10 бит полезного сигнала.
Ключевые слова: механические испытания, тензодатчик, микроконтроллер, аналого-цифровой преобразователь, механические свойства, твердое тело.

Розроблений і створений оригінальний програмно-апаратний комплекс оцифрування аналогового сигналу, що забезпечує багатоканальність збору даних з тензометричних датчиків на базі 32-х розрядного мікроконтролера. Ця система дозволяє проводити механічні випробування твердих тіл на розтягування (стискування), а також контролювати умови експерименту (температура, магнітне поле і тому подібне). Створений комплекс також дозволяє визначати і вивчати активаційні параметри пластичної деформації в металах і сплавах при випробуваннях на розтягування. При цьому швидкість реєстрації деформаційних процесів може складати близько 10^{-3} $с^{-1}$ і точність вимірів не менше 10 біт корисного сигналу.
Ключові слова: механічні випробування, тензодатчик, мікроконтролер, аналого-цифровий перетворювач, механічні властивості, тверде тіло.

Preliminaries

When studying mechanical properties and activating parameters of solids, modern science predominantly employs strain gauge systems. The analog signal coming from strain gauges wants amplification, its further recording and processing of the data obtained. Precision of measuring mechanical properties of solids for various types of testing is estimated by means of: the strain coefficient, temperature stability of strain gauges and the signal amplifier, the degree of amplification of the signal being tested, and the choice of analog signal registration system. Existing strain gauge systems of computer diagram registering when testing samples employ signal amplification, for example, with the help of a strain test station with further sending the data to a two-dimensional recorder. Such systems bear certain limitations: record lag, lack of possibility to monitor an experiment and to process diagrams for calculating deformation parameters. This paper is aimed at design and development of an original soft- and hardware system digitizing the analog system and providing multichannel data collection, a desired speed and accuracy of measurements, resistance to temperature drift, displaying diagrams, and possibility to estimate deformation parameters in devices for mechanical testing.

Measuring system

The designed system can be used for measuring load and deformation when testing samples on tension (compression). For registration of load and deformation values we use resilient members shaped as a hollow cylinder or a planar wafer to which strain gauge sensors are glued in a bridge pattern [1]. Data from the sensors are collected by means of a multichannel system which converts the output analog signal from the strain gauge bridge into a digital code. As a result, we get data packets which are transmitted to a PC for further procession. In this process we use original software designed for translation of an obtained digital code into values of load-tension (compression) with further drawing a tension (compression) curve and recording the data in a file to be analyzed in the Origin software.

Figure 1 represents a structural diagram of a two-channel system of digitizing and processing test data.

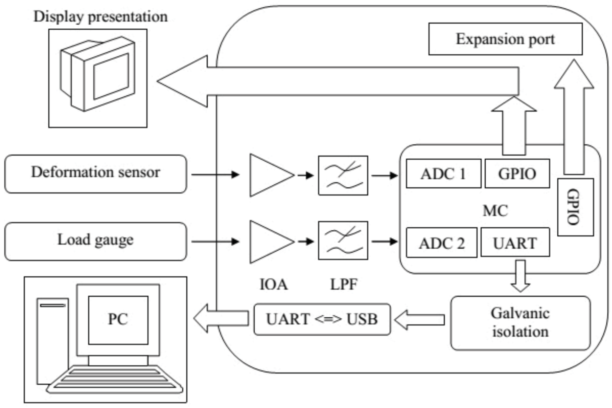

Fig.1. In the structural diagram of the soft- and hardware system LPF stands for low-pass filter, IOA – instrumental operational amplifier, MC – 32-bit microcontroller, ADC – analog-digital converter, GPIO – general purpose input/output, UART – universal asynchronous receiver/transmitter.

Strain gauge sensors are practically always activated in a bridge pattern and glued to the load gauge for temperature compensation on the arms of the strain gauge bridge and for elimination of temperature drift. For accurate measurements metal film strain gauge sensors are most frequently used. Their strain gauge coefficient is considerably lower than that of semiconductors. A distinctive feature of metal strain gauge sensors is a more rigorous linear dependence of variation of resistance on extension and lower temperature drift, which provides better precision in estimating parameters under testing. Since metal strain gauge sensors possess a low strain gauge coefficient, their output signal wants more amplification – about 1,000 times or over. The task set can be effectively solved with the help of instrumental operational amplifiers (IOA), for example, the ones manufactured by Analog Devices [2] and Burr-Brown (TI) companies [3].

Owing to the low value of the tested signal of the strain gauge sensor and the high coefficient of gain in the instrumental operational amplifier, it is rational to employ low-pass filters adjusted to 50 Hz in order to weaken outward interference induction. Further on the amplified and filtered signal goes to the input of an analog-digital converter (with 12-bit capacity and digitization frequency of 1 Msps) built in a 32-bit microcontroller (MC) manufactured, for example, by STMicroelectronics company [4]. After that the outcome gets averaged according to 200 measurements for further formation of data packets and sending them to the Universal Asynchronous Receiver/Transmitter (UART), which virtually reaches a theoretical limit of 2,5 Ksps (corresponds to one measurement in 0.0004 second).

Importantly, the main source of interference induction in a measurement system can be PC power circuits a frequency of 30-200 kHz. To weaken high-frequency interference induction and to protect a PC, the designed system contains an optic isolation implemented in two optically-coupled isolators (for data input into/output from an MC). The isolation physically separates the measuring block of the system from channels of communication with the PC by means of a USB port. To make the process of setting the balance of strain gauge bridges easier, the measurement block contains a graphic display representing tension (compression) curves and current values of the signal entering the ADC.

For a more accurate estimation of mechanical properties of solids in various physical fields and control over the parameters (thermal, magnetic, radiation, etc.) of these fields it seems sensible to upgrade the soft- and hardware system. With this end in view, we have designed an expansion port (GPIO) to which both outer ADC and other devices can be connected. Their modes of functioning are to be set by an algorithm (for instance, switching on/off of a heater at given temperatures, thermal mode, intensity of the magnetic field, radiation intensity, etc.).

Software

To process test curves we use a packet of developed software designed in an object-oriented programming language Delphi and the Origin program. The developed program performs primary data processing: it receives data sent from an MC to a PC, translates them from a digital code into measurands (load-extension) calibrated by standards.

Figure 2 contains the program interface. Most of the interface is taken by the space displaying the curve of samples deformation which is drawn in the course of receiving test data (Point 1). Along the x-axis and the y-axis we get image of values of extension in millimeters and of load in kilograms respectively. Calibrating is carried out with the help of a pop-up menu (Point 2) providing conversion of voltage values in volts into measurands. The program also provides adjustment of digitization speed (Point 3), the desired value of which is translated into a digital code and transmitted to the inner MC register. Further data from the ADC are recorded in a packet to be sent to a PC in a set mode of register interrupt.

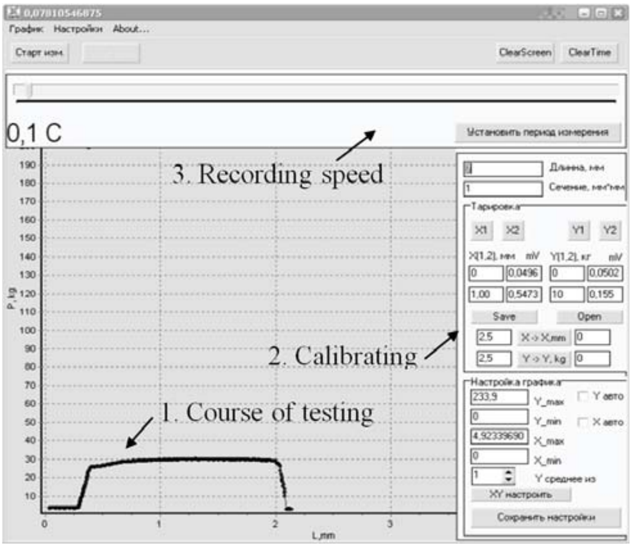

Fig. 2. Interface of the program of data collection and representation on a PC: 1 – space displaying the curve in the course of testing, 2 – the pop-up menu for calibrating, 3 – the interval between two measurements, in seconds.

The array of experimental data is imported to the Origin program for further procession and numerical calculus. Figure 3 contains the interface of the Origin program and deformation curves of steel X18H10T in various structural conditions. Visualized deformation curves can be converted into a format convenient for printing. Basic deformation parameters such as, for example, yield point $\sigma_{0.2}$, rupture point σ_B, total extension ε_o, proportional extension ε_p can be measured automatically.

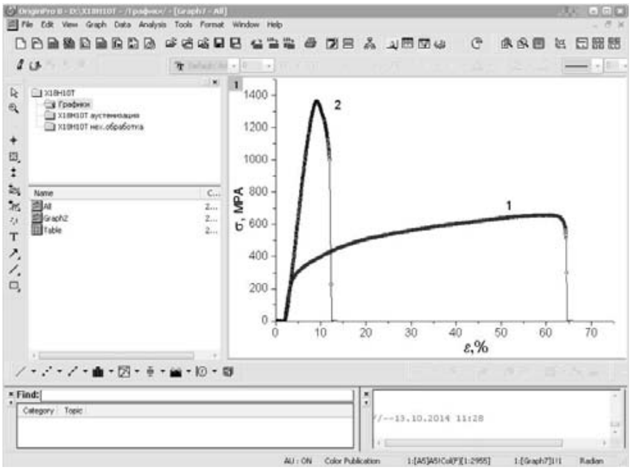

Fig. 3. Experimental deformation curves of steel X18H10T processed in the Origin program environment: 1 – austenitic condition, 2 – after rolling deformation.

The developed system of registration of deformation parameters and the software employed also permit measuring and analyzing activation parameters of plastic strain in metals and alloys when tested for tension.

Conclusions

The research resulted in design and development of an original soft- and hardware system digitizing the analog signal which provides multichannel data collection from strain gauge sensors during mechanical tests of solids. Outputting experimental data to a PC enables calculations of deformation and activation parameters of solids.

The given soft- and hardware system provides measurement accuracy of no less than 10 bits of useful signal. The measurement interval can be set within the range of 0,001 ÷ 5 sec with a tuning step of 0,001 sec. The speed of data exchange between the MC and a PC can reach 921600 bps, which provides sufficient speed for registration of deformation processes of about 10^{-3} c^{-1}.

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1. Gindin I.A., Kravchenko S.F., Starodubov Ya.D., Chechelnitskiy G.G. И.А., Scientific Instruments and Methods, № 2, 240 (1967).
2. Manufacturer of Electronic Components *Analog Devices* [Electronic resource]: Database. — Access mode: http://www.analog.com/ru/index.html.
3. Manufacturer of Electronic Components *Texas Instruments* [Electronic resource]: Database. — Access mode: http://www.ti.com/.
4. Manufacturer of Electronic Components *STMicroelectronics* [Electronic resource]: Database. — Access mode: http://www.st.com/web/en/home.html.