

AUTOMATIZATION SYSTEM FOR AEROPHYSICAL EXPERIMENTS*

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Introduction

The present-day aerophysical experiment features high rapidity of processes under study, a great number of parameters to be simultaneously measured, and great complexity of both experimental procedures and numerical algorithms used to gather data and process them. All these necessitate using automation data acquisition and processing systems.

First automation systems for aerophysical experiments developed in the Institute of Applied and Theoretical Mechanics, SB RAS, in 70th were designed around a centralized data acquisition system based on the second-generation electronic computer «Minsk-32». To facilitate the data input, a multi-channeled data acquisition system based on commercially available «Analog» modules was developed [1]. This system had found then wide application in studying relatively slow processes. To introduce automation into the study of rapid processes, a rapid multi-channeled measuring system «Spectrum» was constructed [2]. This system contained up to 20 individual high-speed measuring modules with 8-digit analog-to-digital coders and a memory intended to store 512 indications. With the help of the above system, weight, drainage and some other tests on existing wind-tunnel facilities were automatized [3].

In 80th, a second-generation automated system for scientific research based on mini- and microcomputers was introduced in the Institute. This system had a three-level structure. At the bottom (object) level, in a close vicinity to experimental setup, automated experimenter's places were organized based on satellite microcomputers [4]. To feed the experimental information into the computers, CAMAC equipment was used. The experimental data thus obtained were transferred through a communication minicomputer SM-4 to the upper level, where big computers BESM-6 and El'brus were used to accumulate the experimental data and give them a final treatment [5]. Approximately at the same time a transputer-based automated system for aerophysical studies was developed [6].

In connection with the wide introduction of personal computers, as well with the obvious obsolescence and physical degradation of available data acquisition facilities, there was posed a problem to develop a next-generation automated system for aerophysical studies based on modern electronic modules, computers and telecommunication means and employing advanced software facilities and technologies.

The necessity for developing the new automated system was brought about by the following factors:

1. It was necessary to attach the worldwide significance to the Institute's wind-tunnel facilities, which were capable of ensuring a broad range of flow parameters (Mach and Reynolds numbers), and bring these facilities to the new technological level.
2. It was necessary to improve the accuracy and reliability of obtained experimental information.
3. The automation means used in that time were completely out-dated.

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4. There was a need in raising the informative capacity of experiments under run; this need resulted from the necessity to reduce the operation period of experimental setups and, hence, optimize their energy consumption.

5. There was a sound tendency to making automation research systems more flexible and the experiments themselves less time- and labor-consuming.

1. Specific features of the automation system for aerophysical experiment

The present-day automation systems for scientific experiments offer a wide spectrum of opportunities, which simultaneously form their distinctive features. These opportunities are the following:

1. Using personal computers at all levels of the system.

2. The processing power of satellite personal computers was brought to such a high level that it became possible to process all data obtained immediately on the object level.

3. Very often distributed automated research systems are used in which each computer performs some definite duties such as data-acquisition function, exerting control over the experiment, accumulating experimental results, processing them, etc.

4. Flexibility of the means used to adapt an automation system to specific individual requirements allows programmers to write general-purpose software requiring no additional adjustment at the spot. Modification of algorithms in computer programs can be organized in the form of some initial settings to be chosen by the experimenter. Thus, we may speak about a kind of alienation of a software product from its developer. Realization of this approach was attempted during development of the automation system for aerophysical studies for S.A. Chaplygin Siberian Research Academy [7], as well as the automated system for the wind tunnel AT-303 now under construction.

5. The main principle to be adopted nowadays is the use of standard commercially available modules from leading firms-suppliers specialized in particular types of instrumentation. Among such modules, there are 16-channeled analog-to-digital converters, analog-to-digital converters with large-capacity memory intended for measuring rapid processes, input/output cards, etc.

In modern automation systems for experimental studies, network technologies have found wide application [8], which ensure information interchange among different levels of the system [9] and allow easy organization of the storage of both experimental and computed data, and also comparison between them.

The work on the construction of the modern automated data acquisition system was based on the following main principles:

– unification of the data acquisition system on the hardware-interface and software-interface level;

– using, as computation stations, personal or special-purpose computers (IBM PC, Advantech, etc.) with installed modern software facilities;

– modularity; all modules in the system should be designed completely from the viewpoint of their functioning at the data-acquisition controller level and have a standard communication interface with the computation station (RS485 interface for remote apparatus, PCI and ISA interfaces for the station-integrated controllers);

– adaptability; a possibility to reconfigure the system;

– openness; an opportunity should be provided to further develop the system using modules obtained from other firms-suppliers;

– control of metrological characteristics;

– reliability;

– intuitively clear interface.

2. The structure of the automation system for experimental studies

With allowance for all peculiarities of the Institute's experimental facilities and the experimental procedures adopted, all types of the systems for experiment automation may be subdivided into single-level and multi-level systems.

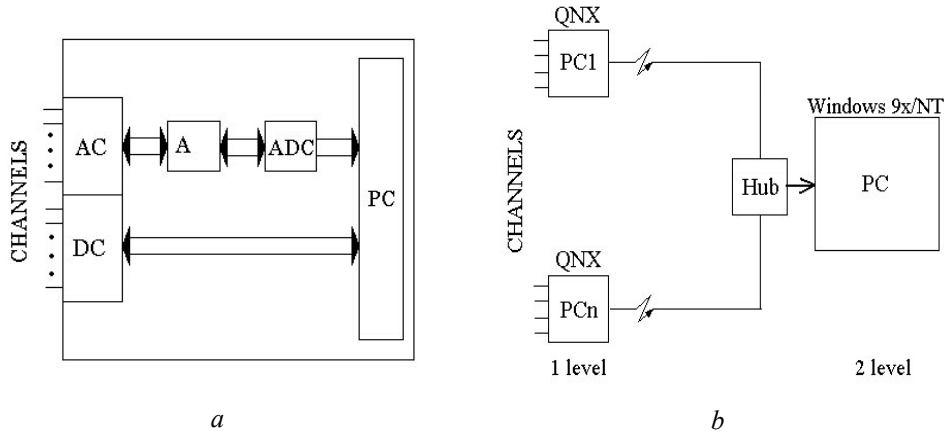


Fig. 1. Single-level automation system (a) and two-level automation system (b).

Single-level automation systems. These systems are to be constructed on one personal computer, being intended for automation of simplest experiments (see Fig. 1,a) that require an automated input of only a limited number of measurement channels into an electronic computer and not very complex processing of experimental data. As a rule, such systems are based on the operating system Windows 95/98/2000 and are installed immediately on the working computers of users-experimenters.

Multi-level automation systems. Unlike single-level systems, multi-level (in most cases, two-level) automation systems are to be constructed on the basis of a system of computers, being used for the automation of most complex and expensive experimental setups (see Fig. 1,b). Such system allows the input of experimental data through several tens/hundreds of channels working in the real-time operation mode.

On the first level, such systems employ communication means intended for exchange of information with an intercoupler used to digitize the measured data and transfer them, through the Ethernet or through a standard serial communication channel (such as RS-232 or RS-485 channels), to the second level of the system. The operation of the program on the first level is executed under a real-time operating system, the QNX one for example, which belongs to Unix-like multi-flow data processing systems. This system provides full-functional support for low-level hardware facilities as well as reliable operation of the whole data acquisition complex.

On the second level, there is one or several computers used to control both the data input into the system and the measurement procedure itself. At the same level, the processing, accumulation, representation in a desired form, and, where required, transfer of experimental data through a local computer network to other computers is ensured. The operation of the upper-level computers is controlled by the standard operating system Windows 95/98/2000.

Within the project under way, several general-purpose variants of intercouplers are being under design, each intended for working in different operation modes and therefore characterized by different operating speeds, digit capacities, number of measurement channels used, etc.

With the help of the automation system, the following tasks will be performed:

- automation of data acquisition procedures for slowly varying aerophysical quantities;
- automation of data acquisition procedures for rapid processes;
- input of optical flow-visualization data into an electronic computer;
- synchronization between data acquisition procedures used to study rapid processes and/or to grasp optical information for slow processes;
- displaying measured values of slowly varying quantities for a setup operator and leading engineer;

- exerting control over a wind-tunnel facility (or its individual components) and also over the experimental procedure;
- ensuring due interaction between the data acquisition system and an aerodynamic database.

3. Some examples of using the system for experiment automation

As an example, consider some automation systems for aerophysical experiments, constructed around the above-described principles, for a number of the Institute's wind-tunnel facilities: T-313, T-326, and AT-303 ones.

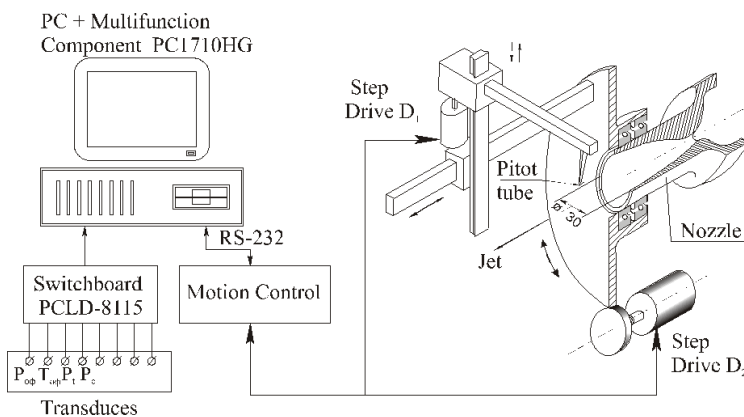


Fig. 2. Measurement scheme adopted on the jet module of the hypersonic wind tunnel T-326.

Figure 2 illustrates the measurement scheme adopted on the jet module of the hypersonic T-326 wind tunnel and realized on the basis of a multifunction card PCI-1710HG. The data acquisition problem devised for such an experiment allows immediate observation on a display of the functional relation $Pt(f)$ that takes place under various experimental conditions.

Another example of the up-to-date approach to the problem of

development of an automation system for experiments is application of automation means to experimenting on the wind tunnel AT-303.

The system is based on the 14-slot chassis of a commercially available computer IPC-610 (Advantech). The complete variant of the AT-303 starting system employs 50 analog and digital measurement channels, and also 15 control channels. The AT-303 control system allows automatic preparation of the wind tunnel for the experiment and starting it under certain initial conditions. The launch of the wind tunnel is fully automated and lasts for 2-3 seconds. During the procedure, at preset moments the registration system is initiated, the for-chamber gets the working gas, the pushing gas is fed to hydraulic cylinders, the gas-compression process is initiated, and the nozzle valve opens which ensures the working-gas ejection. Some data illustrating the work of the system for monitoring current experimental conditions are shown in Fig. 3. The data cover one operation cycle of the wind tunnel. The figure

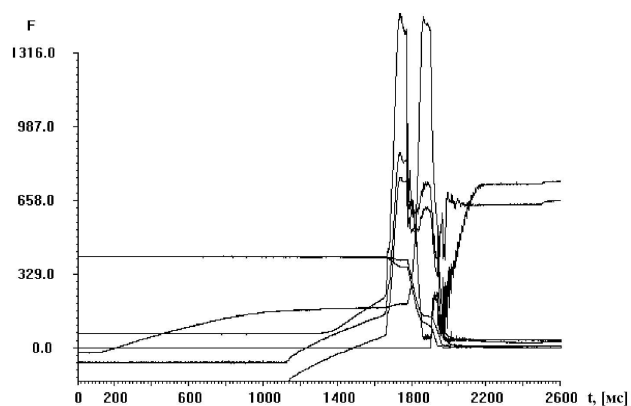


Fig. 3. Example of using an analog-input card PCL818HG in the control system of AT-303.

shows the indications of five pressure gages installed at characteristic points of the working-gas source, as well as indications of two piston displacement transducers. These data well illustrate the compression process.

Summary

In the course of the present work, the main operation principles for present-day automation systems intended for aerophysical studies have been formulated, and a construction concept for such systems has been worked out. Several actual data acquisition and control systems have been developed and introduced into research practice.

In the future, the developed software and hardware facilities will be extended to cover all other experimental facilities of ITAM.

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